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# THESIS

**NETWORKING REQUIREMENTS ANALYSIS FOR ENGINEERING 2000**

by

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March, 1996

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The Cruise Weapons community wants to evaluate its baseline network and define the characteristics of its Engineering 2000 target network. In this thesis, we develop and execute a methodology for completing these actions. By following this methodology, we compare the community's current requirements with its current capabilities to produce our baseline evaluation. Then, we predict the future requirements and capabilities. From this, we produce our target definition. In our baseline evaluation, we find that the current network does not provide sufficient reach, range, responsiveness, user support, or workgroup support. In addition, we find that it is too complex to maintain or manage effectively. In our target definition, we determine that the future network should be a simple, centrally managed and maintained system that supports all users, including afloat customers and mobile employees. Furthermore, we determine that the network should handle simple messages, multi-version documents, and engineering drawings. In order to provide these capabilities, we recommend that the community streamline its applications suite, discard unnecessary computing assets, produce formal maintenance and management policies, and establish a network operations center. In addition, we recommend that the community implement peer-to-peer networking systems within workgroups, take advantage upgrading LAN technology at the local level, and continue working with DoD service providers for wide area communications..

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# NETWORKING REQUIREMENTS ANALYSIS FOR ENGINEERING 2000

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# ABSTRACT

The Cruise Weapons community wants to evaluate its baseline network and define the characteristics of its Engineering 2000 target network. In this thesis, we develop and execute a methodology for completing these actions. By following this methodology, we compare the community's current requirement with its current capabilities to produce our baseline evaluation. Then, we predict the future requirements and capabilities. From this, we produce our target definition. In our baseline evaluation, we find that the current network does not provide sufficient reach, range, responsiveness, user support, or workgroup support. In addition, we find that it is too complex to maintain or manage effectively. In our target definition, we determine that the future network should be a simple, centrally managed and maintained system that supports all users, including afloat customers and mobile employees. Furthermore, we determine that the network should handle simple messages, multi-version documents, and engineering drawings. In order to provide these capabilities, we recommend that the community streamline its applications suite, discard unnecessary computing assets, produce formal maintenance and management policies, and establish a network operations center. In addition, we recommend that the community implement peer-to-peer networking systems within workgroups, take advantage of upgrading LAN technology at the local level, and continue working with DoD service providers for wide area communications.

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## LIST OF ACRONYMS

| | |
|---|---|
| 4G10 | Harpoon Systems Engineering Division |
| 4G11 | Harpoon Canister Systems Engineering Branch |
| 4G12 | Harpoon Trainable Launcher Systems Engineering Branch |
| 4G13 | Advanced Programs and Computer Programming Branch |
| 4G20 | Harpoon Equipment Engineering & Change Management Division |
| 4G21 | Harpoon Weapons Control Systems Engineering Branch |
| 4G22 | Harpoon Missile and Launching Systems Engineering Branch |
| 4G23 | Engineering Change Management and FMS Support Branch |
| 4G40 | Tomahawk Equipment Engineering Division |
| 4G41 | Tomahawk Installation Branch |
| 4G42 | Tomahawk Equipment Engineering Branch |
| 4G43 | Tomahawk Armored Box Launcher Branch |
| 4G44 | Tomahawk Integration Branch |
| 4G50 | Tomahawk Advanced Systems Division |
| 4G51 | Tomahawk Advanced Systems Engineering Branch |
| 4G52 | Tomahawk Computer Software Engineering Branch |
| 4G53 | ATWCS Branch |
| 4G54 | Tomahawk Systems Engineering Branch |
| AAL | ATM Adaptation Layer |
| AIS | Automated Information Systems |
| ANSI | American National Standards Institute |
| ASIC | Application Specific Integrated Circuit |
| ATM | Asynchronous Transfer Mode |
| ATWCS | Advanced Tomahawk Weapon Control System |

| | |
|---|---|
| AUTODIN | Automated Digital Network |
| CAD | Computer Aided Design |
| CAM | Computer Aided Manufacturing |
| CBC | Construction Battalion Center |
| CMP | Cruise Missile Program Office |
| CNA | Certified NetWare Administrator |
| CNE | Certified NetWare Engineer |
| CONUS | Continental United States |
| COSAL | Coordinated Shipboard Allowance List |
| COTS | Commercial Off-the-Shelf |
| CPE | Customer Premises Equipment |
| CPU | Central Processing Unit |
| CRC | Cyclic Redundancy Check |
| CS | Convergency Sublayer |
| CSMA/CD | Carrier Sense Multiple Access/Collision Detection |
| CW1 | Cruise Weapons One (File Server) |
| CWD | Cruise Weapons Systems Department |
| DISA | Defense Information Systems Agency |
| DISN/NAVNET-IP | Navy Network |
| DLCI | Data Link Connection Identifier |
| DMS | Defense Messaging System |
| DoD | Department of Defense |
| DoN | Department of the Navy |
| DOS | Disk Operating System |
| DPPSO | Defense Publications and Printing Service Office |
| DREN | Defense Research and Engineering Network |
| EDN | Electronic Data Network |

| | |
|---|---|
| E-mail | Electronic Mail |
| FDDI | Fiber Distributed Data Interface |
| FTP | File Transfer Protocol |
| FTSC | Fleet Technical Support Center |
| Gb | Gigabit |
| GOTS | Government Off-the-Shelf |
| HCI | Human-Computer Interface |
| HEC | Header Error Correction |
| HP | Hewlett-Packard |
| ISDN | Integrated Services Digital Network |
| ISEA | In-Service Engineering Agent |
| IT | Interdomain Trust |
| ITM | Information Technology Management |
| IXC | Inter-Exchange Carrier |
| JCALS | Joint Computer-Aided Acquisition and Logistics System |
| JEDMICS | Joint Engineering Drawing Management and Info Control System |
| kb | Kilobit |
| LAN | Local Area Network |
| LAO | Lockheed-Martin Austin Operation |
| LEC | Local Exchange Carrier |
| MAC | Media Access Control |
| Mb | Megabit |
| Mbps | Megabits per Second |
| MILNET | Military Network |
| MRC | Maintenance Requirement Cards |
| NAVAIR | Naval Air Systems Command |
| NAVSEA | Naval Sea Systems Command |

| | |
|---|---|
| NEWNET | NAVSEA Enterprise-Wide Network |
| NIC | Network Interface Card |
| NNI | Network Node Interface |
| NPS | Naval Postgraduate School |
| NSWC DD | Naval Surface Warfare Center's Dahlgren Division |
| NSWC PHD | Naval Surface Warfare Center's Port Hueneme Division |
| PC | Personal Computer |
| PDC | Primary Domain Controller |
| PEP | Paperless Environment Project |
| PM | Physical Medium |
| PMA-282 | Cruise Missile Weapon System Project Management Assistant |
| PVC | Permanent Virtual Circuit |
| RAM | Random Access Memory |
| RBOC | Regional Bell Operating Company |
| RISC | Reduced Instruction Set Computer |
| SAIC | Science Applications International Corporation |
| SAP | Service Access Point |
| SAR | Segmentation and Reassembly |
| SCCI | Southeastern Computer Consultants, Incorporated |
| SEIA | System Engineering Integration Agent |
| SMDS | Switched Multimegabit Data Service |
| SMTP | Simple Mail Transfer Protocol |
| SNI | Subscriber Network Interface |
| SPX/IPX | Sequenced Packet Exchange/Internet Packet Exchange |
| STP | Shielded Twisted Pair (Cabling) |
| STP | Shielded Twisted Pair |
| SVC | Switched Virtual Circuit |

| | |
|---|---|
| SWEF | Surface Warfare Evaluation Facility |
| TAFIM | Technical Architecture for Information Management |
| TC | Transmission Convergence |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| TECHMAN | Technical Manual |
| TEXN | Tomahawk Engineering Exchange Network |
| THT | Token Holding Time |
| TIRS | Tomahawk Information Retrieval System (File Server) |
| TOMIS | Tomahawk Information System |
| TRT | Token Rotation Time |
| TTRT | Target Token Rotation Time |
| TWCS | Tomahawk Weapon Control System |
| UNI | User-Network Interface |
| UTP | Unshielded Twisted Pair (Cabling) |
| UTP | Unshielded Twisted Pair |
| VC | Virtual Channel |
| VCI | Virtual Channel Identifier |
| VINES | Virtual Network System |
| VP | Virtual Path |
| VPI | Virtual Path Identifier |
| WAN | Wide Area Network |
| WWW | World Wide Web |

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# I. INTRODUCTION

## A. PURPOSE OF THESIS

### 1. Customer's Goals and Expectations

The Navy's Cruise Weapons community supports the Harpoon and Tomahawk cruise missile programs [Ref. 1]. These programs are important components of our nation's maritime force structure [Ref. 2].

In order to support Harpoon and Tomahawk more effectively, the Cruise Weapons community initiated the Engineering 2000 project [Ref. 3]. This project was designed to lead to the establishment of a robust information architecture encompassing the community's engineering, logistics, and management functions [Ref. 4].

One aspect of Engineering 2000 involves the development of a community-wide "network of networks." This computer network must give a geographically distributed set of government and contractor entities an improved ability to access and exchange mission-critical information [Ref. 5]. It must support the community's efforts to improve its concurrent engineering, life cycle support, and program management capabilities [Ref. 3]. Furthermore, it must comply with the appropriate Department of Defense (DoD) and Department of the Navy (DoN) standards [Ref. 6].

The Cruise Weapons Systems Department (CWD) of the Naval Surface Warfare Center's Port Hueneme Division (NSWC PHD) is responsible for developing this network [Ref. 4]. As a part of the plan for discharging this responsibility, managers from the organization have requested research assistance from the Naval Postgraduate School's (NPS) Systems Management Department [Ref. 1]. Specifically, these managers have asked NPS to help them answer six questions:

1. What are our current requirements?
2. What are our current capabilities?
3. How well do these capabilities match our requirements?
4. What are our anticipated requirements for the year 2000?
5. What capabilities will be available in the year 2000?
6. How can we incorporate these capabilities to meet our anticipated requirements [Ref. 1]?

The first three questions are part of a *baseline evaluation*, while the second three are part of a *target definition*. By answering these six questions, the management team hopes to gain the insight required to identify the projects associated with moving the computer network from its baseline state to the target state [Ref. 7].

### 2. Department of Defense Guidance

CWD is using *DoD's Technical Architecture Framework for Information Management* (TAFIM) to help it manage this portion of the Engineering 2000 project. By so doing, the organization is in compliance with a directive issued by the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence in March, 1995 [Ref. 8]. This directive included the following statement:

> "Effective immediately, new DoD information systems development and modernization programs will conform to the TAFIM... [Ref. 8]"

TAFIM's Volume Four (DoD Standards-Based Architecture Planning Guide) provides general guidance concerning the baseline evaluation and target architecture definition processes. It does not, however, contain a detailed plan for using TAFIM in a specific problem environment. CWD or its agents must, therefore, develop a methodology for applying TAFIM's principles to the Engineering 2000 project.

### 3. The Project Team's Efforts

We, the members of the NPS project team, developed a process that bridged the gap between TAFIM's general guidance and the specific needs of CWD. After developing this process, we applied it to the Engineering 2000 problem environment. As a result of our efforts, we were able to answer the research questions.

## B. LITERATURE REVIEW

To augment the guidance provided by TAFIM, we reviewed two contractor-produced studies. The first of these was the CWD-directed *Feasibility Study for Engineering 2000*, a product of the Science Applications International Corporation (SAIC). It examined the current software, hardware, and network architecture to determine the feasibility of integrating automated tools to provide a common infrastructure for the future [Ref. 4]. The second study was directed by NSWC PHD in conjunction with its Paperless Environment Project (PEP). This study was conducted by the EG&G Support Services Corporation (EG&G). It was helpful in understanding efforts currently underway to create an environment for electronic communication at NSWC PHD [Ref. 9].

While both of these studies provide critical background information regarding CWD and its environment, the focus of each is insufficient to answer all of the Engineering 2000 questions. The SAIC Feasibility Study focuses primarily on the integration of software tools for CWD. The EG&G Study focuses on electronic communications for NSWC PHD's needs. Both studies provide information in answering the Engineering 2000 questions.

## C. OUTLINE OF CHAPTERS

This thesis outlines our work. The main body contains eight chapters. These chapters are organized as follows:

1. In Chapter II, “Methodology,” we describe our model of the ideal computer network and discuss how we applied this model to the development of the baseline characterization and target definition methodologies.
2. In Chapter III, “Baseline Environment,” we examine the work organization, information, and applications. From this examination, we draw conclusions about the current requirements.
3. In Chapter IV, “Baseline Network,” we examine the networking suite. From this examination, we draw conclusions about the current capabilities.
4. In Chapter V, “Baseline Evaluation,” we compare the requirements and capabilities to produce our evaluation of the baseline system.
5. In Chapter VI, “Target Environment,” we examine trends in industry and DoD. From this examination, we draw conclusions about the anticipated requirements.
6. In Chapter VII, “Target Evaluation,” we examine emerging technologies. From this examination, we identify the capabilities that may play a role in helping CWD meet its anticipated requirements.
7. In Chapter VIII, “Project Conclusions,” we review our findings and present a set of short-term and long-term recommendations for improving CWD’s computer network. We finish by discussing the research that must be conducted in order to complete the next step of the TAFIM process.

# II. METHODOLOGY

## A. OVERVIEW

We began our research by developing the Four Concentric Rings model. This model was derived from TAFIM's Volume Four. It captured our vision of the ideal computer network.

We used the Four Concentric Rings model to help us evaluate the baseline network and define the target network. In the baseline evaluation, we compared the requirements and capabilities of 1995. In the target definition, we helped CWD identify the capabilities it needs to meet the anticipated requirements of 2000.

## B. THE FOUR CONCENTRIC RINGS MODEL

### 1. Summary

In the Four Concentric Rings model, the network and its environment are seen as the set of rings depicted in Figure 1. The *work organization ring* represents the structured collection of network users. The *information ring* represents the information that is presented to and received from the users. The *applications ring* represents the applications that transform user-readable information into network-readable data. Finally, the *network ring* represents the managed collection of nodes, protocols, and transmission links.

The outer three rings form the *environment*, while the innermost ring forms the *network*. The environment drives the requirements, while the network provides the required capabilities. In this project, we can study the environment, but we cannot manipulate it. On the other hand, we can study *and* manipulate the network.

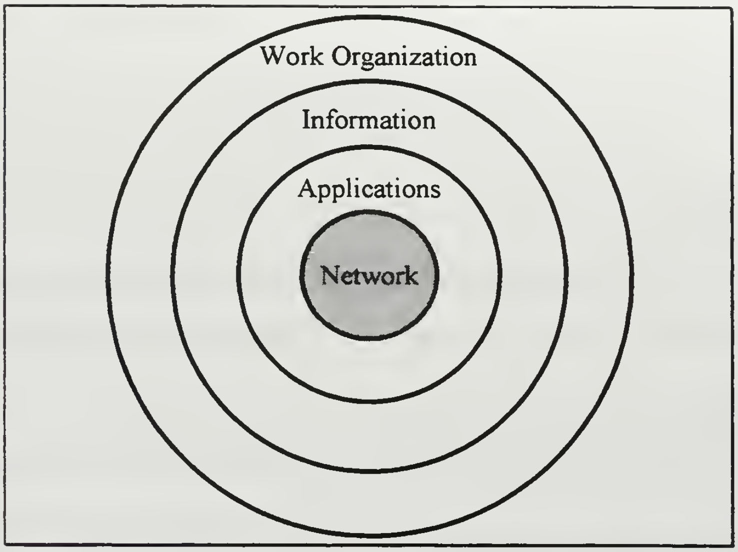


**Figure 1. Four Concentric Rings**

### 2. Work Organization

The *work organization* is the structured collection of network users. In order to perform their jobs effectively, users must be able to exchange information among themselves, even if that requires communicating over great distances. Their tasks normally do not *require* that they have detailed knowledge of the applications that present the information or the network elements that carry the information.

The organization is driven by its *structures, people, political forces,* and *culture* [Ref. 10]. The key *structural* factors are missions, objectives, internal designs, and external designs. The *people* can be characterized in terms of their responsibilities, access requirements, levels of experience, and technical backgrounds. Relevant *political forces* include the sources of conflict, major factions, and methods for resolving conflicts between those factions. The significant *cultural factors* are the key values and methods of interaction. In a networked computing environment, they may also include the degree of attachment to a particular operating system, application, or type of hardware.

### 3. Information

Organizational entities collect, process, disseminate, use, and store *information* while performing their missions. By examining the information and the entities that interact with it, we can identify the key *information domains.*

Within each domain are a number of *flows.* These flows link the entities that collect, process, disseminate, use, and store information. Each flow plays a role in determining how the domain interacts with the rest of the environment and the network.

Flows can be categorized in terms of the information being transferred and the media used to represent that information. They can also be characterized according to the names and locations of the associated organizational entities.

### 4. Applications

*Applications* link information domains and network elements. They help the organization attain such capabilities as document management and electronic messaging.

At the origin of a telecommunications link, applications accept the user's inputs, transform them into network-readable data, and relay the data to the highest level of the network's protocol stack. At the destination, they accept data from the network, transform them into human-readable information, and present the information to the user.

Ideally, users should focus exclusively on the operational aspects of each application. If an application is part of an effective Human-Computer Interface, users are free to ignore the technical details and concentrate on the information they need.

An analysis of the applications suite should include a study of the required functional capabilities. These capabilities identify *what* the applications need to do in order to support the organization effectively.

After looking at the required functional capabilities, one should focus on the applications that exist to attain them. Each application can be classified in terms of its mission, sponsor, host sites, host platforms, and associated user groups.

### 5. Network

The *network* is a managed collection of nodes, protocols, and transmission links. These elements support the environment by allowing applications to interoperate. By so doing, they help information flow freely between people and organizational entities.

One can examine the network by identifying its subnetworking scheme. During this process, the analyst can categorize each subnetwork in terms of its geographic scope, transmission technology, network operating system, and logical and physical topologies.

After examining the subnetworking scheme, one should study a sample of the nodes, protocols, and transmission links. Nodes can be characterized according to their purposes, central processing units, memory capacities, secondary storage capacities, and operating systems. Protocol stacks can be categorized in terms of their upper, transport, network, and lower layers [Ref. 11]. Finally, transmission links can be identified by their arrangements of physical media, switches, and relay nodes.

## C. BASELINE EVALUATION METHODOLOGY

### 1. Overview

Through our baseline evaluation effort, we addressed the following questions:

1. What are CWD's current requirements?
2. What are CWD's current capabilities?
3. How well do the capabilities meet the requirements?

We used a three-step process to answer these questions. First, we examined the environment and drew conclusions about the requirements. Second, we examined the network and drew conclusions about the capabilities. Third, we compared the requirements and capabilities to produce our baseline evaluation. This process is summarized in Figure 2.

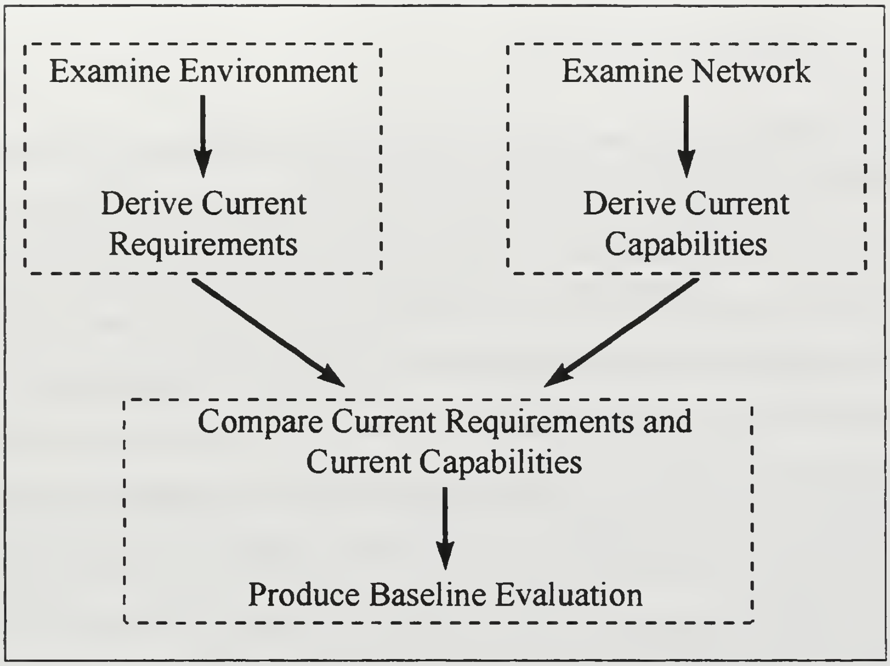


**Figure 2. Baseline Evaluation Methodology**

### 2. Examining the Environment

In the first step, we used site visits, interviews, and a literature review to gather data concerning the work organization, information, and applications. Then, we applied this data to our Four Concentric Rings model. By so doing, we were able to identify the key characteristics of the environment.

After identifying the key characteristics, we used three analytical tools to help us increase our understanding of the environment. First, we used entity-relationship diagrams to identify the organization's needs. Second, we used data flow diagrams to identify the information's needs. Third, we used functional decomposition diagrams to identify the applications' needs.

At the end of the process, we reviewed the key characteristics and the three sets of needs. From this review, we derived the top-level requirements.

### 3. Examining the Network

In the second step, we used interviews, site visits, operating log examinations, and a literature review to gather data concerning the networking suite. By so doing, we were able to identify the key characteristics of the local area networks (LAN), backbone network, wide area networks (WAN's), and dial-up networks that support CWD.

After identifying the key characteristics, we looked at the levels of service and performance associated with each network. This involved examining the linked entities, geographic locations, information domains, applications, and computing resources. It also involved measuring such parameters as availability, loading, message handling times, and annual costs.

At the end of the process, we reviewed the key characteristics and levels of service and performance. From this review, we derived the top-level capabilities.

### 4. Producing the Baseline Evaluation

In the third step, we used a simple matching process to compare the current requirements and capabilities. During this process, we focused on the requirements that received *inadequate* support from the networking suite. This allowed us to identify the major problem areas.

After completing the comparison, we reviewed the major problems areas. From this review, we derived a set of "shortfalls." These shortfalls represent the areas on which CWD should concentrate while trying to improve its computer network.

At the end of our project, we returned to the list of shortfalls and used it as the basis for a set of short-term recommendations. These recommendations dealt with relatively inexpensive and simple projects that could be undertaken in 1996 to "shorten the gap" between the requirements and capabilities.

## D. TARGET DEFINITION METHODOLOGY

### 1. Overview

Through our baseline evaluation effort, we addressed the following questions:

1. What are the anticipated requirements for the year 2000?
2. What capabilities will be available in the year 2000?
3. How can we apply the future capabilities to meet the anticipated requirements?

We used a three-step process to answer these questions. First, we examined trends in industry and DoD and derived the anticipated requirements. Second, we examined emerging technologies and derived the future capabilities. Third, we compared the anticipated requirements and future capabilities to produce our target definition. Figure 3 summarizes this process.

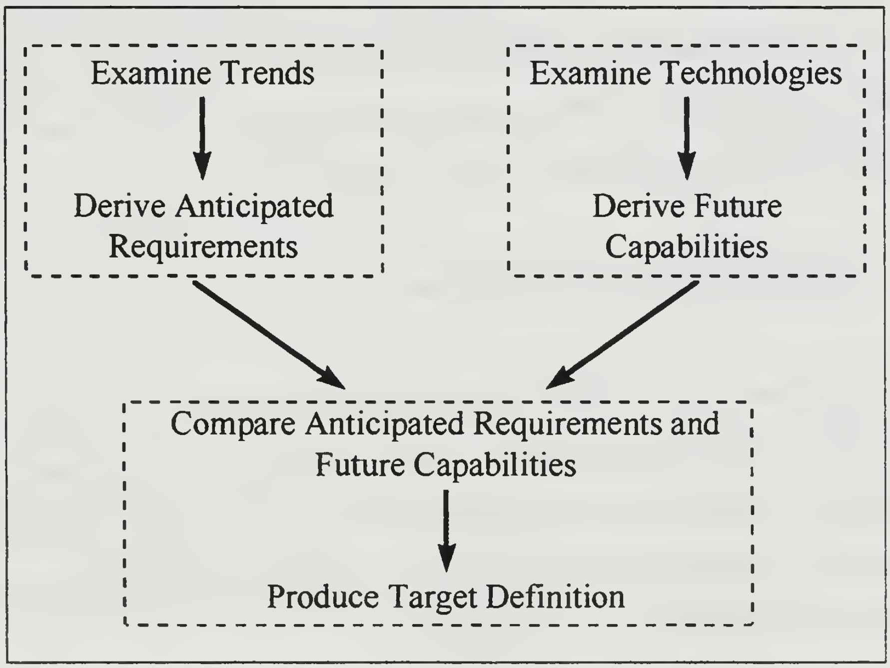


**Figure 3. Target Definition**

### 2. Examining Trends

In the first step, we had to make predictions about the future environment for the CWD target network. Predicting the future is always a risky undertaking. Therefore, to derive a more accurate picture of the future requirements, we examined the *trends* in industry and DoD. We grouped these trends according to the domains of our Four Concentric Rings model. This helped us determine how a trend in industry will, perhaps, become a requirement for CWD's computer network in the year 2000.

### 3. Examining Emerging Technologies

In the second step, we conducted an initial literature review to determine what emerging and expanding technologies have the most potential for affecting a computer network. We limited this review to specific components of a computer network in order to make the project more manageable. These components included: LAN technologies, broadband technologies, network operating systems, transmission media, and network management tools. For each component, we researched the most promising technologies from our initial literature review. This evaluation formed the basis for our estimation of the capabilities available in the future to affect a CWD network.

### 4. Producing the Target Definition

In the third step, we compared the anticipated requirements and future capabilities. The results of this comparison became the basis for our long-term recommendations. These recommendations dealt with relatively expensive and complex projects that could be undertaken over the next five years to help the network evolve into a system that meets CWD's anticipated requirements.

## E. SUMMARY

In the first phase, we focused on the *current* requirements and capabilities (see Figure 4). We derived the requirements by examining the environment. Then, we derived the capabilities by examining the network. At the end of this phase, we compared the requirements and capabilities and identified a set of key shortfalls.

In the second phase, we focused on the relationship between the *anticipated* requirements and *future* capabilities (see Figure 5). We derived the requirements by examining trends in industry and DoD. Then, we derived the capabilities by examining emerging technologies. At the end of this phase, we compared the requirements and capabilities and completed our target definition.

We concluded our project by producing a list of short-term and long-term recommendations. The short-term recommendations referred to relatively inexpensive, simple projects that could be undertaken *in 1996* to "shorten the gap" between the requirements and capabilities. The long-term recommendations referred to relatively expensive, complex projects that could be undertaken *over the next five years* to help the network evolve into a system that meets CWD's anticipated requirements.

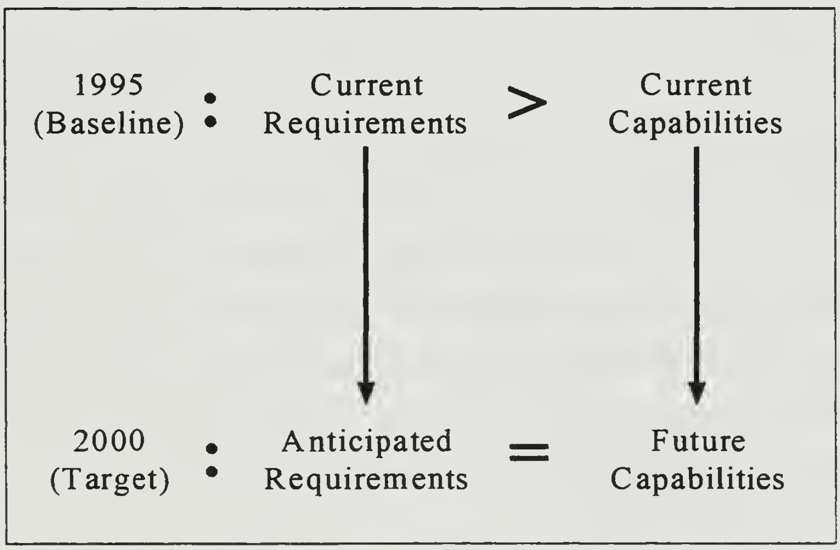


**Figure 4. Methodology Summary**

# III. BASELINE ENVIRONMENT

## A. INTRODUCTION

We examined the environment by studying the work organization, information, and applications. From our examination, we drew conclusions about CWD's networking requirements.

## B. WORK ORGANIZATION

### 1. The Information Factory

CWD is the in-service engineering agent (ISEA) for the Tomahawk and Harpoon programs [Ref. 12]. As such, it is the focal point for the Cruise Weapons community's engineering and logistics activities. These activities benefit the development of new systems and the maintenance of existing systems. [Ref. 6]

To meet its mission requirements, CWD must perform several functions. Most of these functions involve taking data from suppliers, transforming the data into useful information, and delivering the information to customers. Because of this, we can view CWD as a simple "information factory."

Like many factories, CWD is part of a larger organization, one that has a structure filled with seniors, peers, and subordinates. CWD must maintain relationships with these entities in order for it to perform its functions effectively.

A factory would be nothing more than an empty building without managers, administrators, production workers, and maintenance technicians. CWD is not an exception to this rule. It has a large and diverse group of employees who perform or support the production functions. This workforce has needs that must be satisfied.

CWD's workforce, like any other large group of people, is subject to political and cultural forces. The political forces arise from the competition for resources and attention. The cultural forces govern the complex interactions that occur within and

between elements of the population. CWD must take these forces into account when it makes its long-term business decisions.

We examined CWD in the context of the factory model. During this examination, we looked at the suppliers, customers, seniors, peers, and subordinates. Then, we used entity-relationship diagrams to analyze these elements as a complete set. Through this effort, we learned about CWD's organizational structure. After learning about the structure, we looked at the human needs, political forces, and cultural factors. These were the elements that "gave life" to the organization.

### 2. Suppliers

The suppliers are civilian and military organizations that develop and maintain components of the Harpoon and Tomahawk weapon systems. They deliver components that meet the Navy's requirements. In addition, they deliver the related technical data to CWD. The key suppliers include:

1. Lockheed-Martin Austin Operation (LAO), a civilian organization that is located in Austin, Texas[1]
2. Southeastern Computer Consultants, Incorporated (SCCI), a civilian organization that is located in Austin, Texas
3. The Naval Surface Warfare Center's Dahlgren Division (NSWC DD), a military organization that is located in Dahlgren, Virginia
4. The Tomahawk Weapon Control System (TWCS) System Engineering Integration Agent (SEIA), a civilian organization that is located in Saint Louis, Missouri [Ref. 3]

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[1] In 1996, LAO's operations may shift to a Pennsylvania-based firm.

### 3. Customers

The customers operate, maintain, manage, and support deployed Harpoon and Tomahawk systems. The key customers are surface combatants, tenders, shipyards, regional maintenance organizations, logistics commands, training centers, type commands, and operational staffs.

Surface combatants operate and perform organizational-level maintenance on missile systems. They are homeported in such places as Bremerton, Mayport, Norfolk, Pearl Harbor, San Diego, and Yokosuka. They regularly operate in or near the Atlantic, Pacific, and Indian Oceans.

Tenders perform intermediate-level maintenance on missile systems. These ships, like the combatants, are homeported in fleet concentration centers and can be found in forward-deployed areas of operations.

Shipyards install, modify, and overhaul missile systems. They are military or civilian. The shipyards are in Avondale, Bath, Long Beach, and Pascagoula [Ref. 13].

Regional maintenance organizations manage intermediate-level maintenance support for installed missile systems. They and their subordinates are located in San Diego, Norfolk, and the other homeports. [Ref. 6]

Logistics commands ensure that surface combatants, tenders, shipyards, and maintenance commands have the repair parts needed to operate and maintain missile systems. One of the most important logistics commands is the Naval Sea Logistics Center (NSLC). This organization is located in Mechanicsburg, Pennsylvania [Ref. 6].

Training centers ensure that operators and maintenance personnel have the skills required to do their jobs. To perform their mission, they must have updated technical information relating to the Harpoon and Tomahawk systems. The key training centers are located in San Diego and Norfolk. [Ref. 6]

Type commands manage the organizations that maintain, operate, and support missile systems. They ensure that the systems receive the proper levels of maintenance and support, and they ensure that missile-equipped ships are available when operational commanders need them. The type commands are located in San Diego and Norfolk.

Operational staffs employ the missile systems to meet American military objectives. These organizations are located in such places as Norfolk, San Diego, Manama (Bahrain), Gaeta (Italy), and Yokosuka.

### 4. Seniors

CWD has two bosses. One is the Cruise Missile Weapon System Project Management Assistant (PMA-282), an element of the Cruise Missile Project Office (CMP). The other is the Systems Engineering Directorate, an element of the Naval Surface Warfare Center's Port Hueneme Division (NSWC PHD). CWD is responsible for balancing the needs and requirements of these two seniors. [Ref. 6]

PMA-282 is the department's sponsor. It sets the direction and tone, and it procures most of the end-user computing equipment. In addition, it establishes information technology management (ITM) policies for itself and its subordinate organizations. [Ref. 6]

The Systems Engineering Directorate is the department's host. It provides computing and telecommunications support, and it establishes ITM policies for itself and its subordinate organizations. [Ref. 6]

In the factory model, PMA-282 can be seen as the head of the nation-wide manufacturing division, while the Systems Engineering Directorate can be seen as the manager of the local industrial park. Like a real factory, CMP must balance the requirements and policies of its division head and its landlord.

### 5. Peers

CWD peers include the Systems Engineering Departments, Logistics Departments, Automated Information Systems (AIS) Department, and Construction Battalion Center (CBC). All of these peers are located in or near NSWC PHD's "industrial park."

The Systems Engineering Departments, like CWD, are information factories. While CWD focuses on the Harpoon and Tomahawk weapon control systems, these factories focus on missiles, guns, launchers, underway replenishment equipment, and fire

control systems [Ref. 14] . The surface combatants have combat system suites that integrate the outputs of CWD and one or all of the other factories. Because of this, CWD must work closely with its peers to ensure that all of the products work together.

The Surface Warfare Engineering Facility (SWEF) is a specialized element of the Systems Engineering Directorate. It is not an information factory. Instead, it is a testing laboratory where departments can evaluate their products before they deliver them to the customers. The SWEF has working models of many shipboard systems, including the Harpoon and Tomahawk weapon control systems [Ref. 12]. Many of CWD's employees work at the SWEF on a regular basis [Ref. 6].

The Logistics Departments assemble and maintain support packages for each surface combatant. These packages include repair parts, test equipment, maintenance procedures, and technical manuals [Ref. 14]. CWD works with the Logistics Departments to ensure that the customers have the items they need to support the Harpoon and Tomahawk systems effectively [Ref. 6].

The AIS Department is an element of the Systems Engineering Directorate. This department manages the backbone computer network, supports a large collection of Sun workstations, operates World Wide Web (WWW) servers, and provides off-station access to several wide area networks. [Ref. 15]

CBC is the host command for NSWC PHD [Ref. 16]. One of its most important functions, from CWD's perspective, involves the operation of a digital telephone system. CWD makes extensive use of this system in its dial-up networks [Ref. 17].

### 6. Subordinates

Most factories have internal organizations to handle portions of the production process. CWD followed this practice by creating four, product-oriented divisions. Two of these deal with Harpoon, while the other two deal with Tomahawk. The Harpoon divisions are 4G10 and 4G20, and the Tomahawk divisions are 4G40 and 4G50 [Ref.18]. All of these divisions are located in the Port Hueneme facility, but none are "fixed" in terms of their geography. Each has a large group of employees who spend most of the year traveling to shipyards, naval bases, and contractor facilities [Ref. 19].

4G10 is the Harpoon Systems Engineering Division. It has three branches: 4G11, 4G12, and 4G13. 4G11 is the Harpoon Canister Systems Engineering Branch. 4G12 is the Harpoon Trainable Launcher Systems Engineering Branch, and 4G13 is the Advanced Programs and Computer Programming Branch. [Ref. 18]

4G20 is the Harpoon Equipment Engineering and Change Management Division. It has three branches: 4G21, 4G22, and 4G23. 4G21 is the Harpoon Weapons Control System Engineering Branch. 4G22 is the Harpoon Missile and Launching Systems Engineering Branch, and 4G23 is the Engineering Change Management and Foreign Military Sales (FMS) Support Branch. [Ref. 18]

4G40 is the Tomahawk Equipment Engineering Division. It has four branches: 4G41, 4G42, 4G43, and 4G44. 4G41 is the Tomahawk Installation Branch. 4G42 is the Tomahawk Equipment Engineering Branch. 4G43 is the Tomahawk Armored Box Launcher Branch, and 4G44 is the Tomahawk Integration Branch. [Ref. 18]

4G50 is the Tomahawk Advanced Systems Division. It has four branches: 4G51, 4G52, 4G53, and 4G54. 4G51 is the Tomahawk Advanced Systems Engineering Branch. 4G52 is the Tomahawk Computer Software Engineering Branch. 4G53 is the Advanced Tomahawk Weapon Control System (ATWCS) System Engineering Branch, and 4G54 is the Tomahawk Systems Engineering Branch. [Ref. 18]

### 7. Relationships between the Structural Entities

Figures 5 through 12 are entity-relationship diagrams. They show the relationships that exist between CWD, and its suppliers, customers, seniors, peers, and subordinates. By studying these diagrams, we can learn the following lessons.

1. <u>4G10 Division</u> is managed by CWD. It manages 4G11, 4G12, and 4G13. It coordinates with 4G20. 4G10's branches coordinate with each other.

2. <u>4G20 Division</u> is managed by CWD. It manages 4G21, 4G22, and 4G23. It coordinates with 4G10. 4G20's branches coordinate with each other.

3. 4G40 Division is managed by CWD. It manages 4G41, 4G42, 4G43, and 4G44. It coordinates with 4G50. 4G40's branches coordinate with each other.

4. 4G50 Division is managed by CWD. It manages 4G51, 4G52, 4G53, and 4G54. It coordinates with 4G40. 4G50's branches coordinate with each other.

5. AIS Department provides support to CWD.

6. CBC provides support to CWD.

7. CMP manages PMA-282.

8. Customers receive products from CWD. They transmit feedback to CWD.

9. CWD is managed by PMA-282 and the Systems Engineering Directorate. It manages 4G10, 4G20, 4G40, and 4G50. It receives product inputs from the suppliers, and it transmits input requests to the suppliers. It transmits products to the customers, and it receives feedback from the customers. CWD coordinates with the System Engineering Departments and the Logistics Departments. It receives support from CBC and AIS Department.

10. Logistics Departments coordinate with CWD.

11. NSWC PHD manages the System Engineering Directorate.

12. PMA-282 is managed by CMP. It manages CWD.

13. Suppliers transmit product inputs to CWD. They receive input requests from CWD.

14. Systems Engineering Departments coordinate with CWD.

15. The Systems Engineering Directorate is managed by NSWC PHD. It manages CWD.

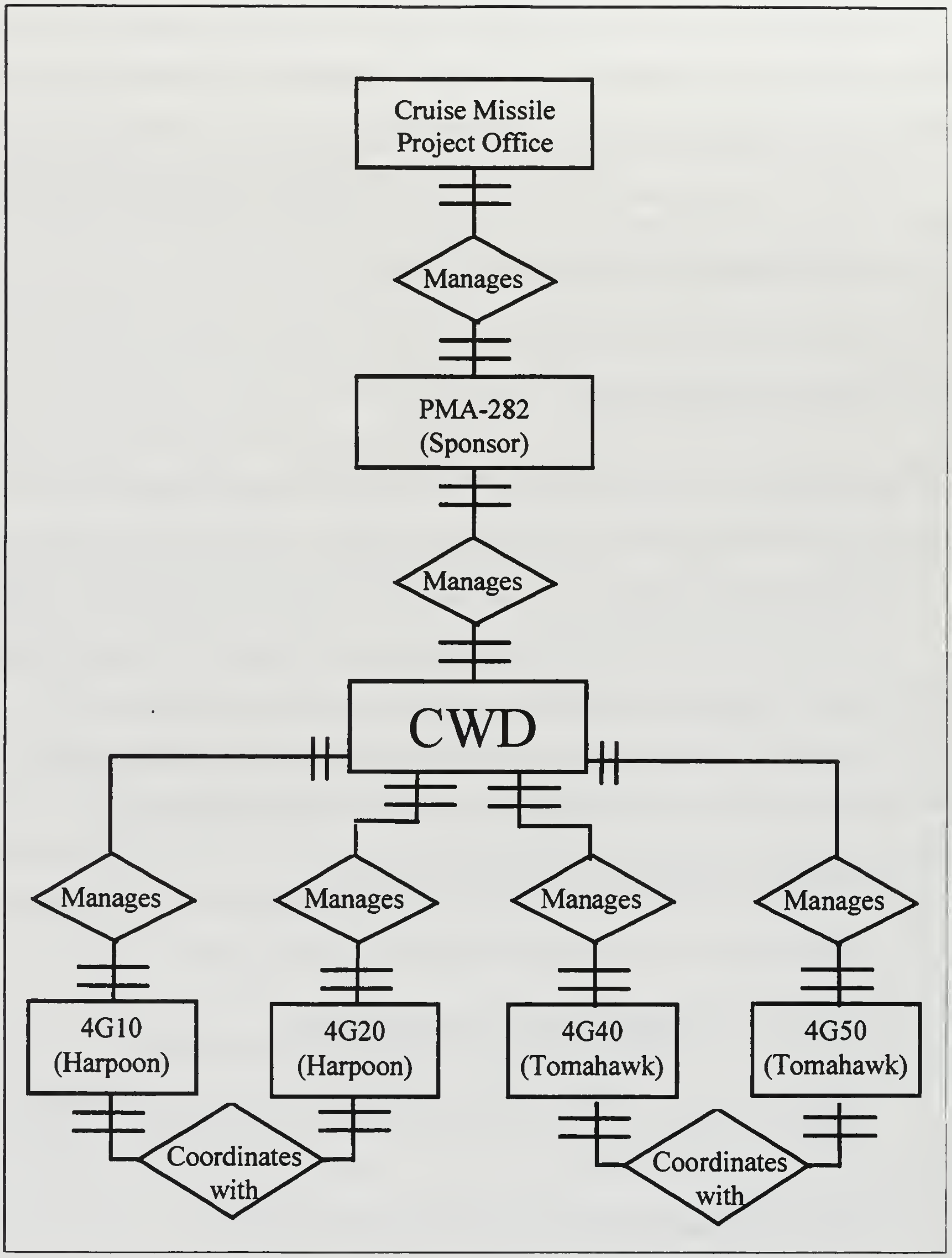


**Figure 5. Entities and Relationships (View One)**

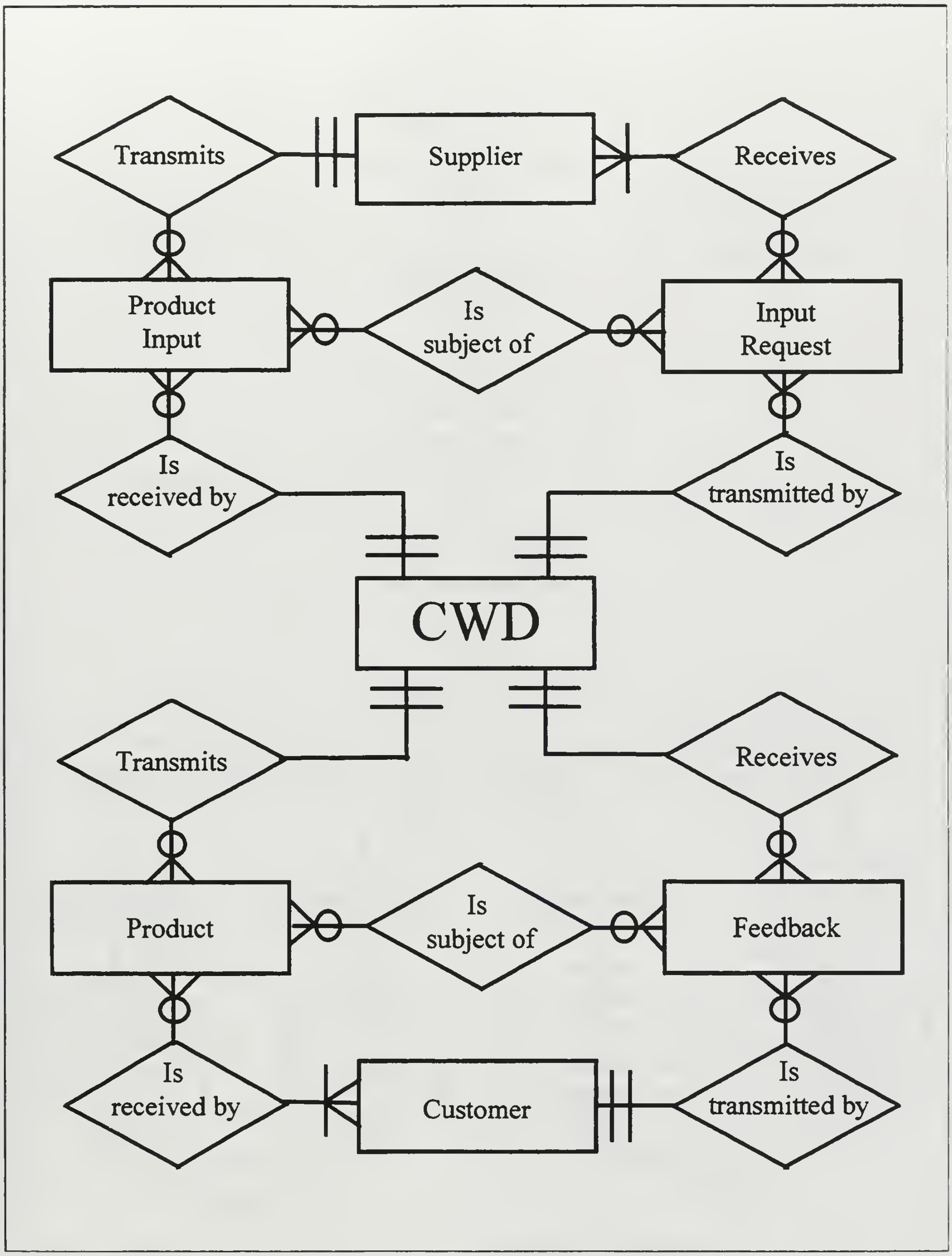


**Figure 6. Entities and Relationships (View Two)**

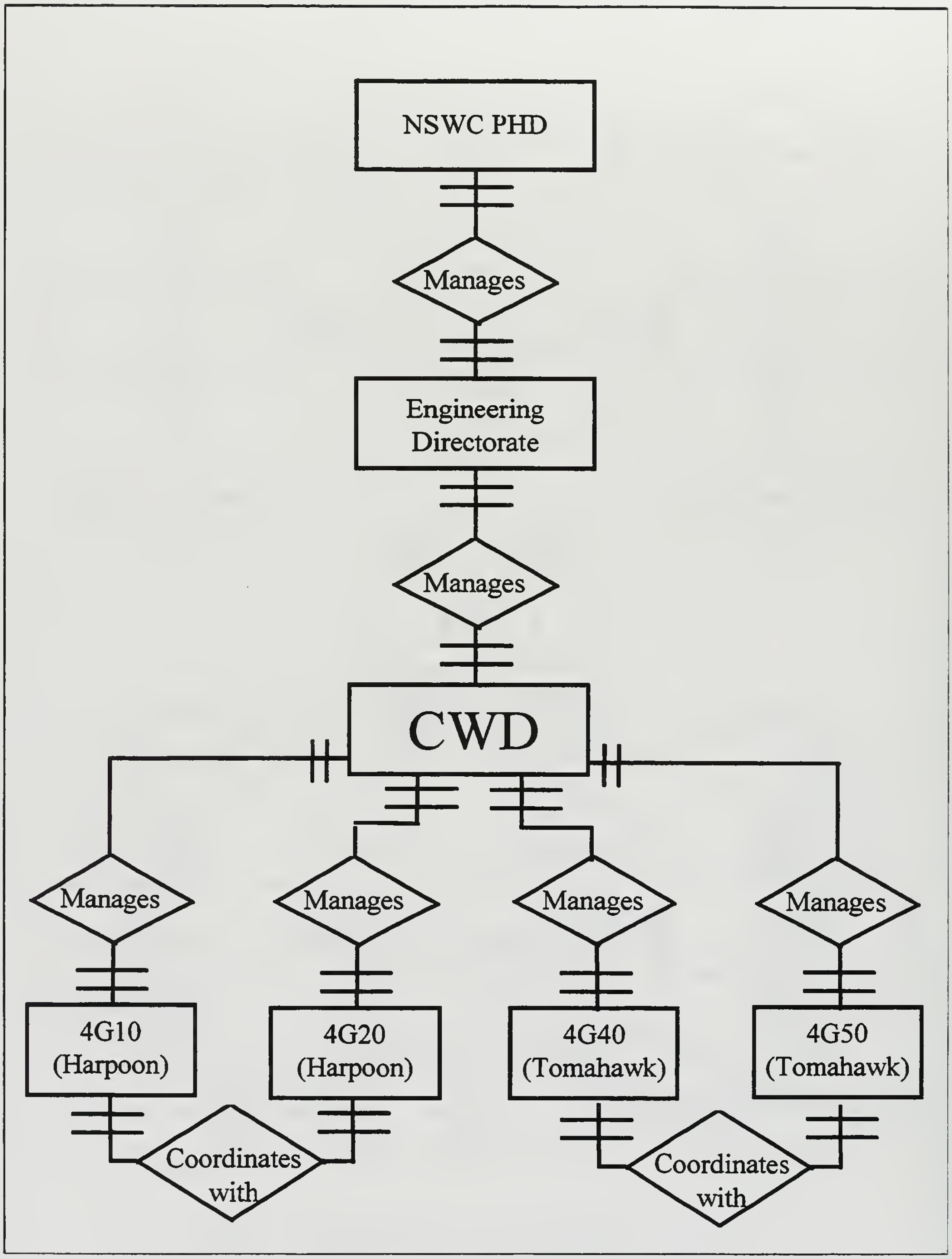


**Figure 7. Entities and Relationships (View Three)**

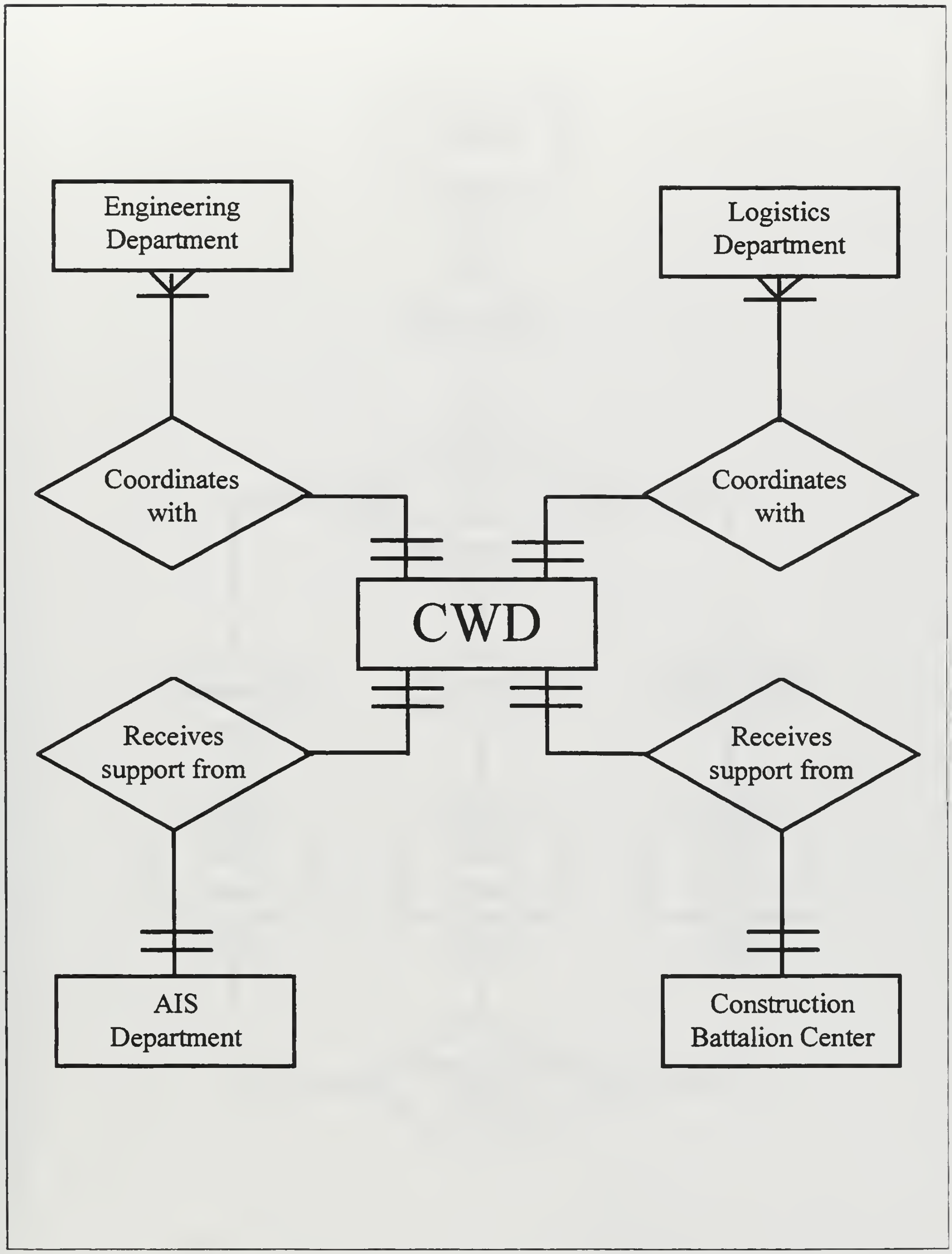


**Figure 8. Entities and Relationships (View Four)**

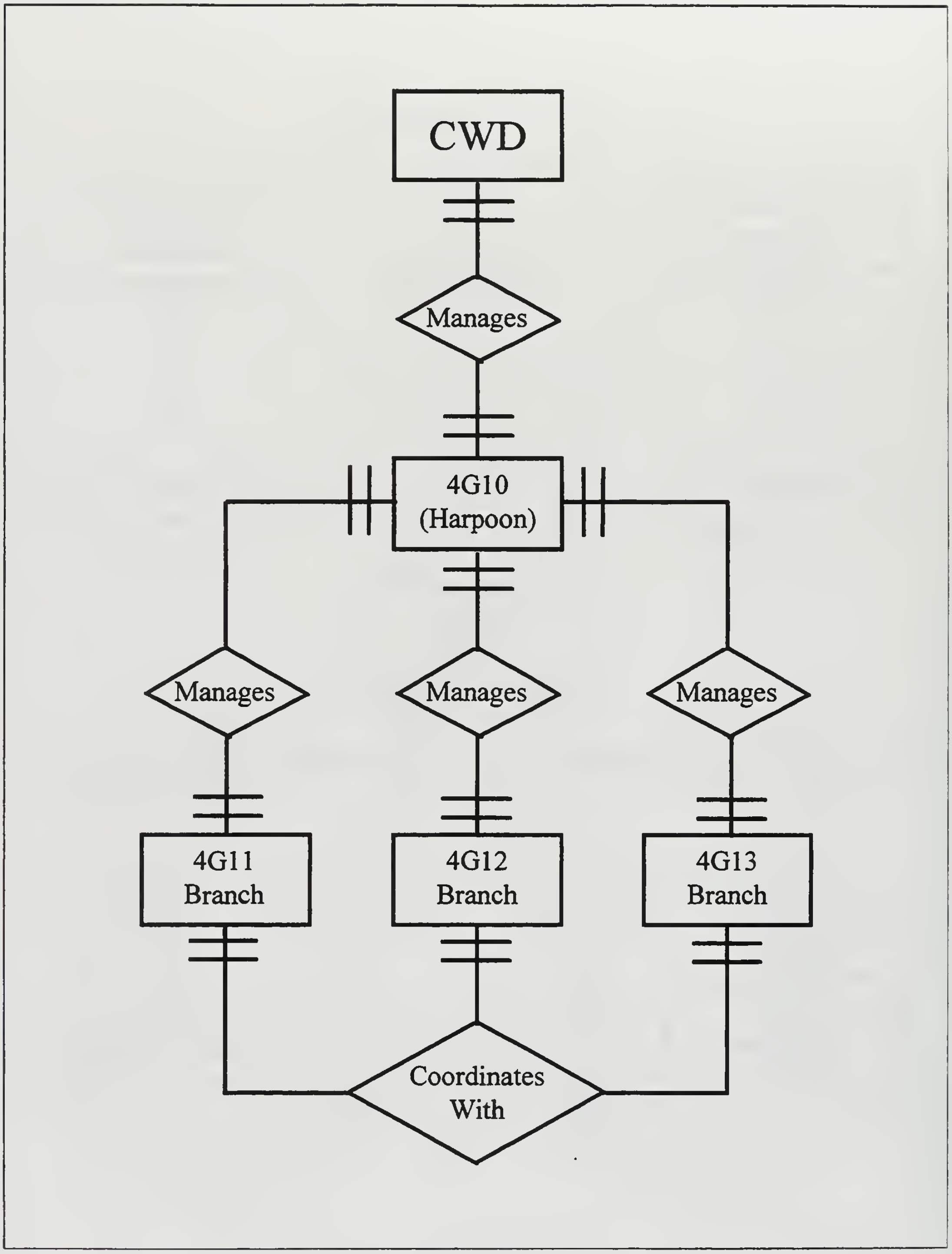


**Figure 9. Entities and Relationships (View Five)**

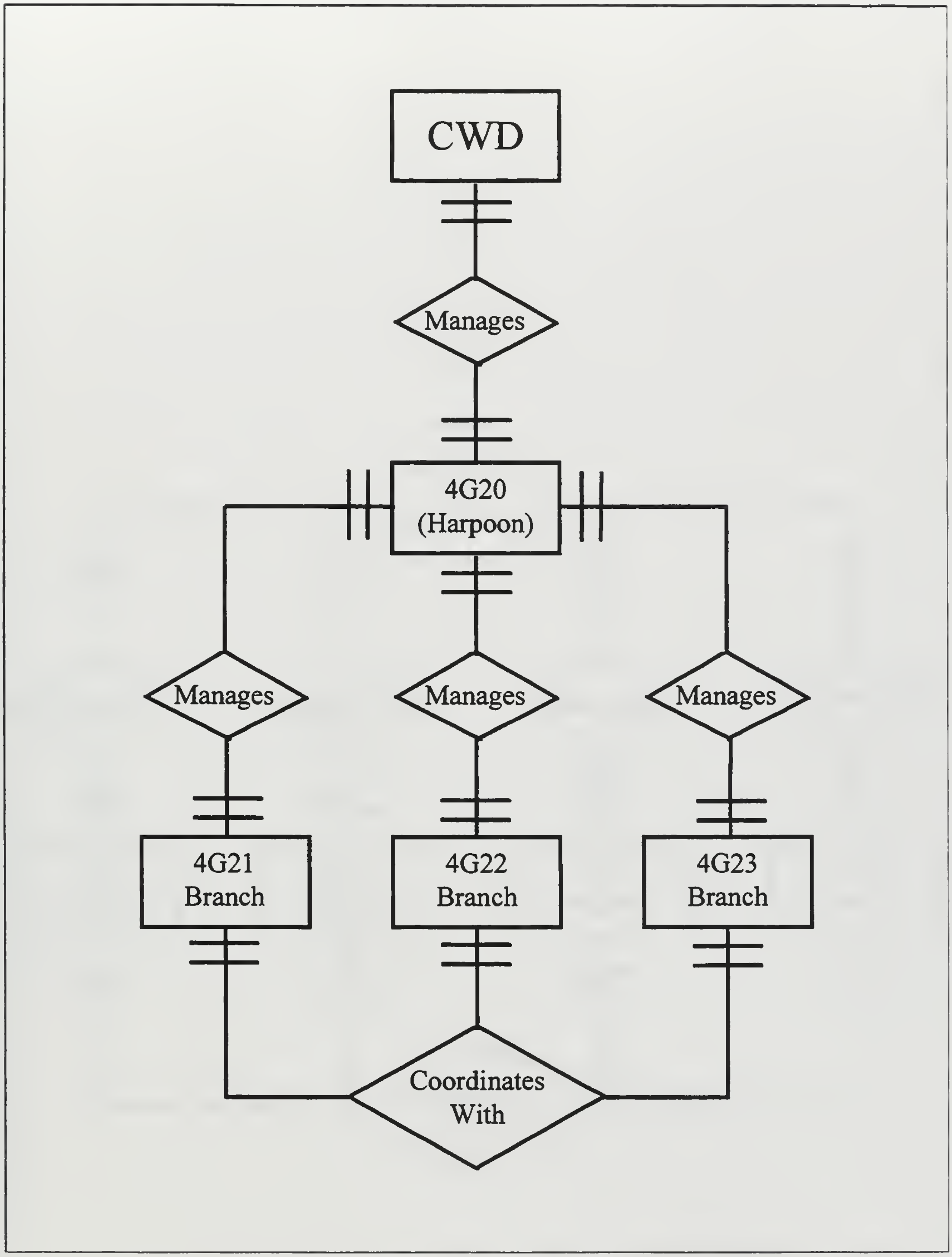


**Figure 10. Entities and Relationships (View Six)**

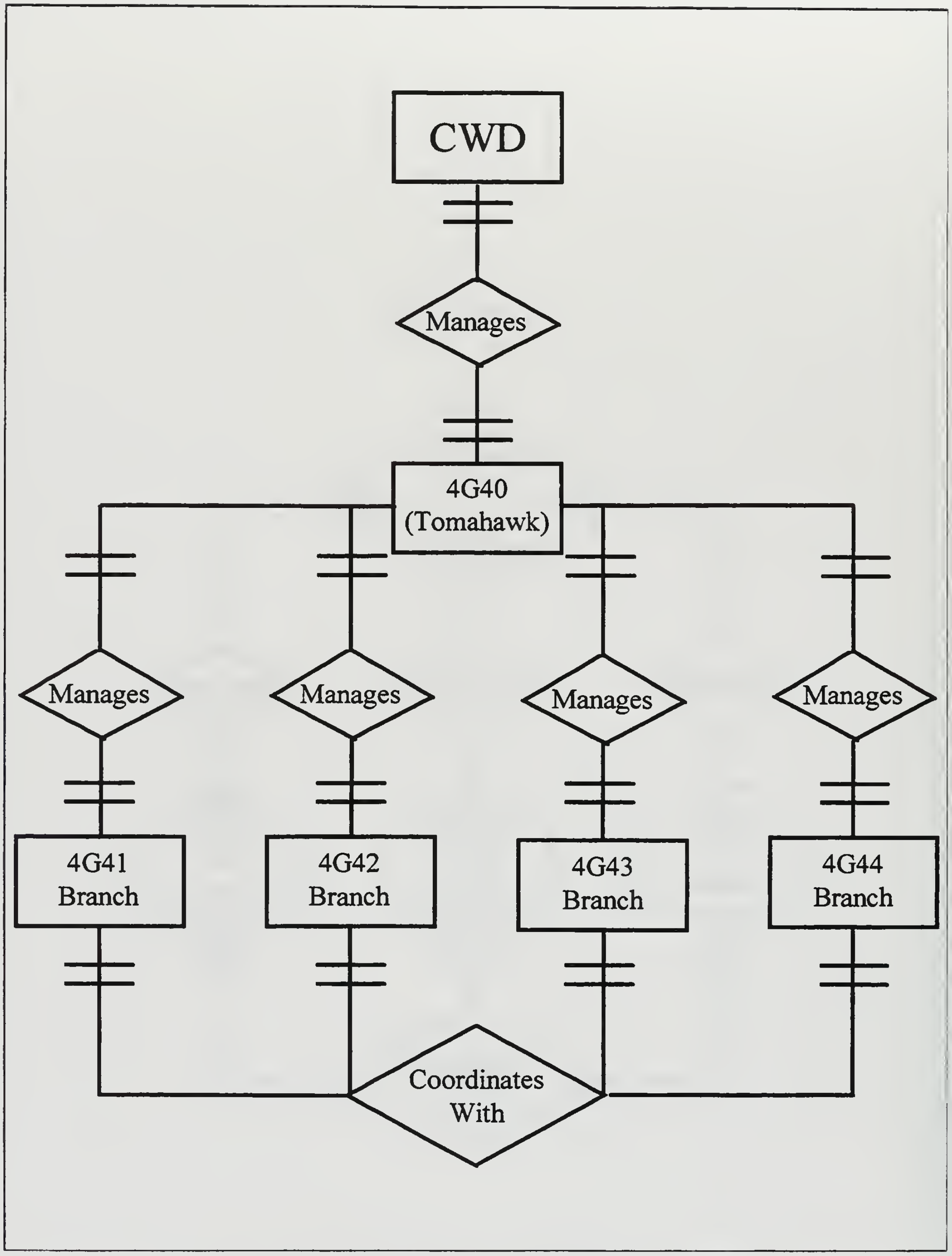


**Figure 11. Entities and Relationships (View Seven)**

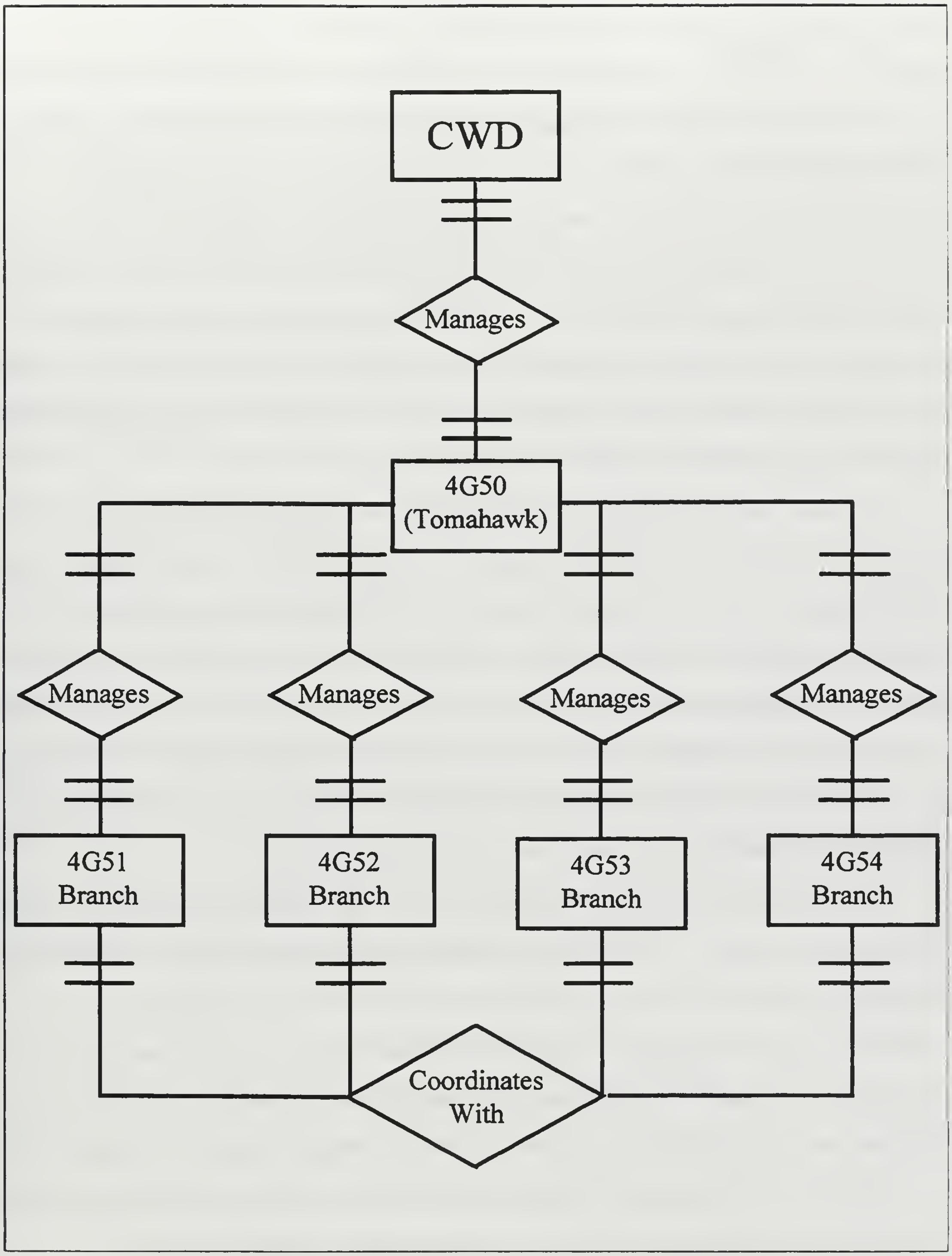


**Figure 12. Entities and Relationships (View Eight)**

### 8. People

Civil-service engineers and engineering technicians account for ninety percent of the 250-person,[2] CWD workforce. The remaining population includes managers, administrators, logisticians, enlisted personnel, and technical support specialists. [Ref. 6]

Most of the engineers specialize in electronics, mathematics, computer science, or mechanical engineering [Ref. 19]. They tend to be comfortable with the computing environment. They like to experiment with the available tools, require very little training, prefer working with the latest technologies, and are not afraid of offering suggestions for improving the information architecture. [Ref. 6]

Managers at the middle and lower echelons are experienced civil-service engineers. At the highest level, the manager is a combat systems engineering duty officer who has a master's degree in computer science. Like the engineering workforce, the management team is well-educated and technically competent. Unlike the engineering workforce, the management team is less enamored with the latest technologies and more concerned about maintaining a stable and economical information system. The managers want to adhere to the appropriate standards, improve business processes, and meet the department's requirements without "breaking the bank." [Ref. 6]

The administrators do not share the engineers' and managers' familiarity with the computing environment . They tend to be passive in their approach to the information architecture. They do not want to experiment or spend time learning about an application. They prefer simple, consistent interfaces that focus on information and minimize the workload. The administrators want the technical support specialists to spend less time "playing" and more time providing training and assistance. [Ref. 6]

CWD does not have any logisticians, but it does work closely with thirty people from the Logistics Directorate. These individuals perform critical tasks for the department. In order to perform these tasks, they need to exchange documents, drawings, and other data sources with CWD's engineers on a regular basis. [Ref. 17]

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[2] Approximate.

The enlisted military personnel are concentrated at the SWEF. These uniformed workers deal with the testing and certification of missile system components. They do not have a great deal of contact with the computing architecture. They do, however, need a way to exchange information with the engineers who work in the main facility. [Ref. 6]

CWD is dependent upon the local expertise provided by its technical support specialists. When users have a specific problem, they visit the appropriate expert. They do not, for the most part, turn to documentation or on-line help. The specialists enjoy being "village witch doctors," but they would prefer to have a computing architecture that is more user-friendly, simpler to maintain, and easier to manage. In addition, they would appreciate a formal training program that fosters professional development and allows them to maintain pace with changes in networking technology. [Ref. 20]

In summary, the workforce has many needs that should be satisfied by the network. Engineers want the network to incorporate the latest technologies. Managers want it to offer stable and economical operations, adhere to standards, and support process improvement. Administrators want it to support applications with better ease-of-use characteristics and gives technicians more time to devote to user support. Logisticians could use a system that helps them exchange documents and drawings. SWEF personnel would like to pass information between remote sites, and technicians want a system that will simplify maintenance and management while giving them more time to focus on training and professional development.

### 9. Politics

CWD must contend with several power-based conflicts. These include the conflicts that exist between development and maintenance obligations, between sponsor and host requirements, and between the technical support staff and AIS Department.

In the 1980's, CWD focused on to the development of new systems. It had little to do with the maintenance of deployed systems. This pleased the engineers, because it allowed them to work in the "exciting" areas of design and implementation. This pleased the managers, because they could control a simple set of project requirements. Finally, it pleased the technicians, because they had few storage and retrieval requirements. [Ref. 6]

In this decade, CWD assumed the responsibility for supporting systems throughout their life cycles. This forced the department to devote resources to the development of new systems and the maintenance of existing systems. Engineers had to spend time on "less glamorous" tasks. Managers had to oversee complex sets of project requirements.[3] Technicians had to find ways to store and retrieve more data.[4] [Ref. 6]

As one might guess, most of the personnel prefer to devote themselves and their resources to development. They want to avoid being assigned to maintenance projects. This puts the management team in a tough situation. It must work hard to ensure that maintenance receives the attention it deserves. This involves making difficult resource allocation decisions and, at times, managing conflicts. [Ref. 6]

The management team's task could be simplified by a network that supports faster data retrieval and manipulation (perhaps, making the maintenance tasks more glamorous), better workgroup communications (to improve project management capabilities), and larger data storage capacities (to make adequate storage resources available to the development and maintenance data sets).

In addition to fighting the development versus maintenance battles, CWD must contend with conflicts between the policies of its sponsor (PMA-282) and the policies of its host (Systems Engineering Directorate). One of the most important conflicts involves the issues surrounding AIS security. The sponsor follows the rules established by the Naval Air Systems Command (NAVAIR), while the host follows the rules established by the Naval Sea Systems Command (NAVSEA). In many cases, CWD must choose between them. Because the sponsor provides the money and long-term direction, CWD

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[3] Development projects tend to follow a logical sequence of steps. Maintenance projects, especially the ones dealing with urgent engineering changes or complicated troubleshooting, can arrive "on the doorstep" with little or no warning. As a manager, one must find a way to "fight the fires" of maintenance while meeting the budget-driven requirements of development.

[4] Today, engineers need access to data relating to systems under development and all deployed versions of existing systems. This presents interesting challenges for the technician dealing with limited storage space.

tends to favor the sponsor's NAVAIR-derived rules. This has weakened the relationship between CWD and its host. [Ref. 6]

One of the sponsor's leading concerns is the completion of the Engineering 2000 project. This project emphasizes the integration of functional applications, remote data access, standardization across the Cruise Weapons community, and the optimization of workflow processes [Ref. 3]. One of the host's biggest concerns is the completion of the Paperless Environment Project (PEP). This project emphasizes compliance with Defense Messaging System (DMS) requirements, the integration of data sources, standardization across NSWC PHD, and improved information security [Ref. 9]. At times, the requirements of the two projects interfere with each other. CWD is, therefore, left to choose between them. Because it must favor the requirements of its sponsor, CWD often finds itself working against the intentions of its host [Ref. 6].

CWD's situation could be improved if its network allowed it to meet the requirements of Engineering 2000 and PEP. This would help the department maintain the critical balance between its sponsor and host relationships.

There is a lot of tension between the AIS Department and CWD. This tension revolves around personality conflicts involving the head of the AIS Department and CWD's technical support specialists. The major issues include the delegation of administrative authority over departmental computing assets, password management, Internet Protocol (IP) address allocation, and routing. [Ref. 17]

CWD depends on the AIS Department. This department holds the licenses for two important applications (*Interleaf* and *Sun Mail*), and it maintains the only platform upon which the *Electronic Data Network*, a mission-critical system, can reside. In addition, it operates the campus backbone and controls access to wide area networks. Thus, CWD cannot afford to let tension degrade its relationship with the AIS Department. [Ref. 20]

Most of the disputes with the AIS Department involve management issues. A computer network with improved management capabilities might ease some of these tensions and allow CWD to achieve "détente" with its neighbor.

### 10. Culture

CWD must consider cultural factors when it constructs its networking requirements. Some of the key cultural factors include the devotion to the branch structure, the need for remote coordination capabilities, and the desire for flexibility in the computing environment.

The branches are the key workgroups within CWD. Personnel identify most strongly with the branches to which they are assigned. They would resist any technology that threatened branch integrity or degraded a branch's ability to work as a team. By the same token, they would embrace any technology that allowed their branch workgroups to perform more efficiently or effectively. [Ref. 18]

The problem becomes more complicated when one considers the distributed nature of the branches. Many branch employees travel on a regular basis. They spend a lot of time at shipyards, contractor facilities, and naval stations. As a result, branches rarely assemble in one location. This has led to the creation of "virtual workgroups" that tie themselves together with E-mail. Group leaders use E-mail to manage subordinates. Group members use it to collaborate on documents or exchange troubleshooting ideas. Many employees find that this arrangement helps them avoid playing "phone tag" throughout the work day. [Ref. 19]

CWD's engineering workforce, the largest segment of the population, believes in the importance of flexible, personalized computing environments. The management team supported this philosophy by deciding that standardization efforts should focus on the "seams," the places where individuals share data in order to do their jobs. [Ref. 6]

CWD's corporate culture is built around small but distributed workgroups and flexible operating environments. In order to perform well, the department's network must have characteristics that fit within this cultural framework.

### 11. Work Organization Summary

Our study of the work organization allowed us to draw the following conclusions:

1. CWD must maintain production, management, and coordination relationships with several organizational entities. These entities can be found in the Continental United States (CONUS), at overseas Naval installations, and on most of the world's oceans.
2. CWD must meet the needs of its engineers, managers, administrators, logisticians, military personnel, and technical support specialists.
3. CWD must contend with the conflicts that exist between development and maintenance obligations, between sponsors and host requirements, and between the technical support staff and the AIS Department.
4. CWD must work within a culture that is built around small but distributed workgroups and flexible operating environments.

## B. BASELINE INFORMATION

### 1. Producer and Consumer

CWD produces and consumes information resources. The produced resources constitute the output of the information factory. They flow from suppliers to "production lines" and from production lines to customers. The consumed resources help CWD operate the factory. They flow vertically between seniors and subordinates and horizontally between peers. The need to maintain the flow of produced and consumed resources greatly influences CWD's networking requirements.

To enhance our understanding of CWD's networking requirements, we decided to model the flow of information resources into, within, and from the department. With this in mind, we constructed the data flow diagrams presented in Figures 13 through 20. Through our study of these diagrams, we learned the following lessons:

1. PMA-282 and the Systems Engineering Directorate transmit <u>management information</u> to CWD. CWD feeds this information into its ISEA processes.

2. CWD uses its ISEA processes to generate <u>management feedback</u>. This feedback is transmitted to PMA-282 and the Systems Engineering Directorate.

3. CWD uses its ISEA processes to generate <u>management information</u>. This information is transmitted to 4G10, 4G20, 4G40, and 4G50.

4. 4G10 and 4G20 use their Harpoon ISEA processes to generate <u>management feedback</u>. By the same token, 4G40 and 4G50 use their Tomahawk ISEA processes to generate <u>management feedback</u>. Both sets of feedback are transmitted to CWD.

5. 4G10 and 4G20 use their Harpoon ISEA processes to generate <u>management information</u>. By the same token, 4G40 and 4G50 use their Tomahawk ISEA processes to generate <u>management information</u>. Each division transmits this

information to its subordinate branches. The branches respond by transmitting management feedback to their divisions.

6. CWD uses its ISEA processes to generate data requirements. These requirements are transmitted to the suppliers.

7. The suppliers transmit data inputs to CWD. CWD feeds these inputs into its ISEA processes.

8. CWD uses its ISEA processes to generate product information. This information is transmitted to the customers.

9. The customers transmit product feedback to CWD. CWD feeds these inputs into its ISEA processes.

10. Coordination information flows between 4G10 and 4G20, the two Harpoon divisions. In addition, it flows between 4G40 and 4G50, the two Tomahawk divisions. Within each of these divisions, coordination information flows among the subordinate branches.

11. The Systems Engineering Departments transmit engineering inputs to CWD. CWD feeds these inputs into its ISEA processes.

12. CWD uses its ISEA processes to generate engineering feedback. This feedback is transmitted to the Systems Engineering Departments.

13. The Logistics Departments transmit logistics inputs to CWD. CWD feeds these inputs into its ISEA processes.

14. CWD uses its ISEA processes to generate logistics feedback. This feedback its transmitted to the Logistics Departments.

15. CWD uses its ISEA processes to generate AIS requirements. These requirements are transmitted to the AIS Department.

16. The AIS Department transmits AIS services and policies information to CWD. CWD feeds the information into its ISEA processes.

17. CWD uses its ISEA processes to generate dial-up telecommunications requirements. These requirements are transmitted to CWC.

18. CWC transmits dial-up services and policies information to CWD. CWD feeds this information into its ISEA processes.

We can simplify our understanding of these information flows by grouping them into three domains: production, management, and coordination.

The production domain contains the requirements and inputs that flow between the suppliers and CWD. It also contains the product information and feedback that flow between CWD and the customers. This domain directly supports the mission of the information factory.

The management domain encompasses the management information and feedback that links CWD to its seniors, CWD to its divisions, and the divisions to their branches. This domain supports the vertical integrity of the organization.

The coordination domain includes the engineering information and feedback, logistics information and feedback, and requirements and services information that flows between CWD and its peers. It also includes the coordination information that flows between 4G10 and 4G20, between 4G40 and 4G50, and between each division's branches. This domain supports the horizontal integrity of the organization.

In the remaining parts of this section, we will examine each of the three information domains. From this examination, we will draw conclusions concerning CWD's information-oriented networking requirements.

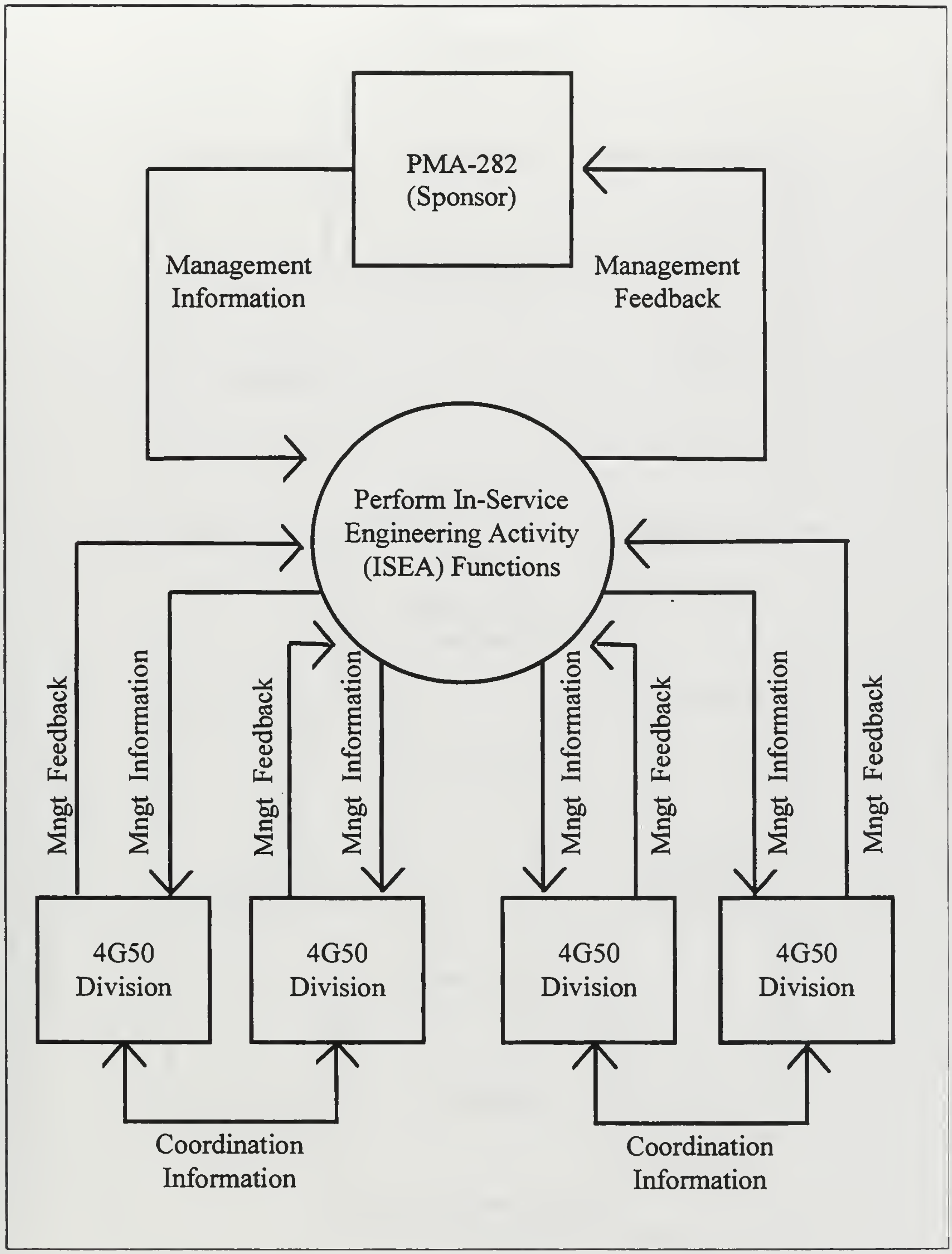


**Figure 13. Information Flows (CWD Perspective -- View One)**

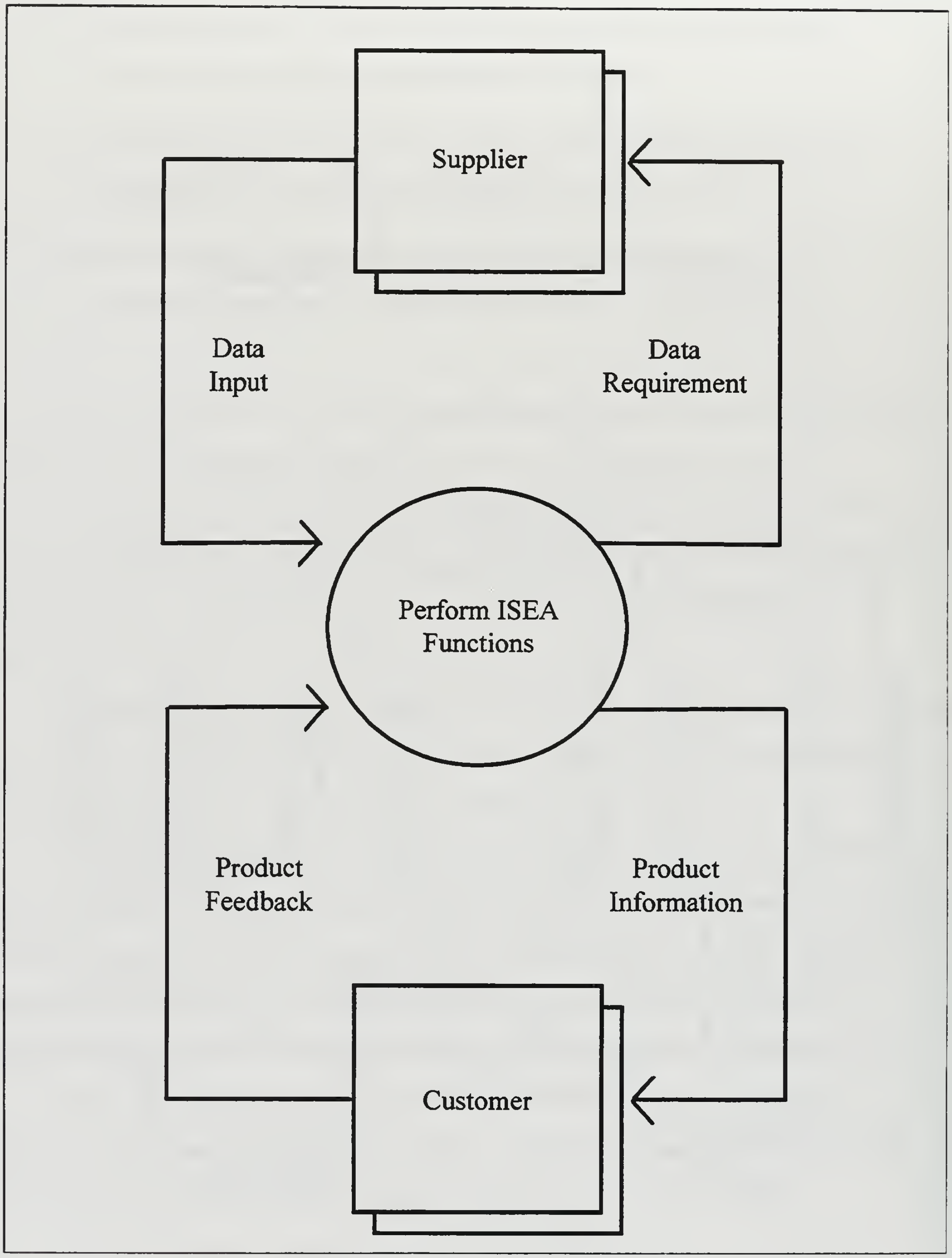


**Figure 14. Information Flows (CWD Perspective -- View Two)**

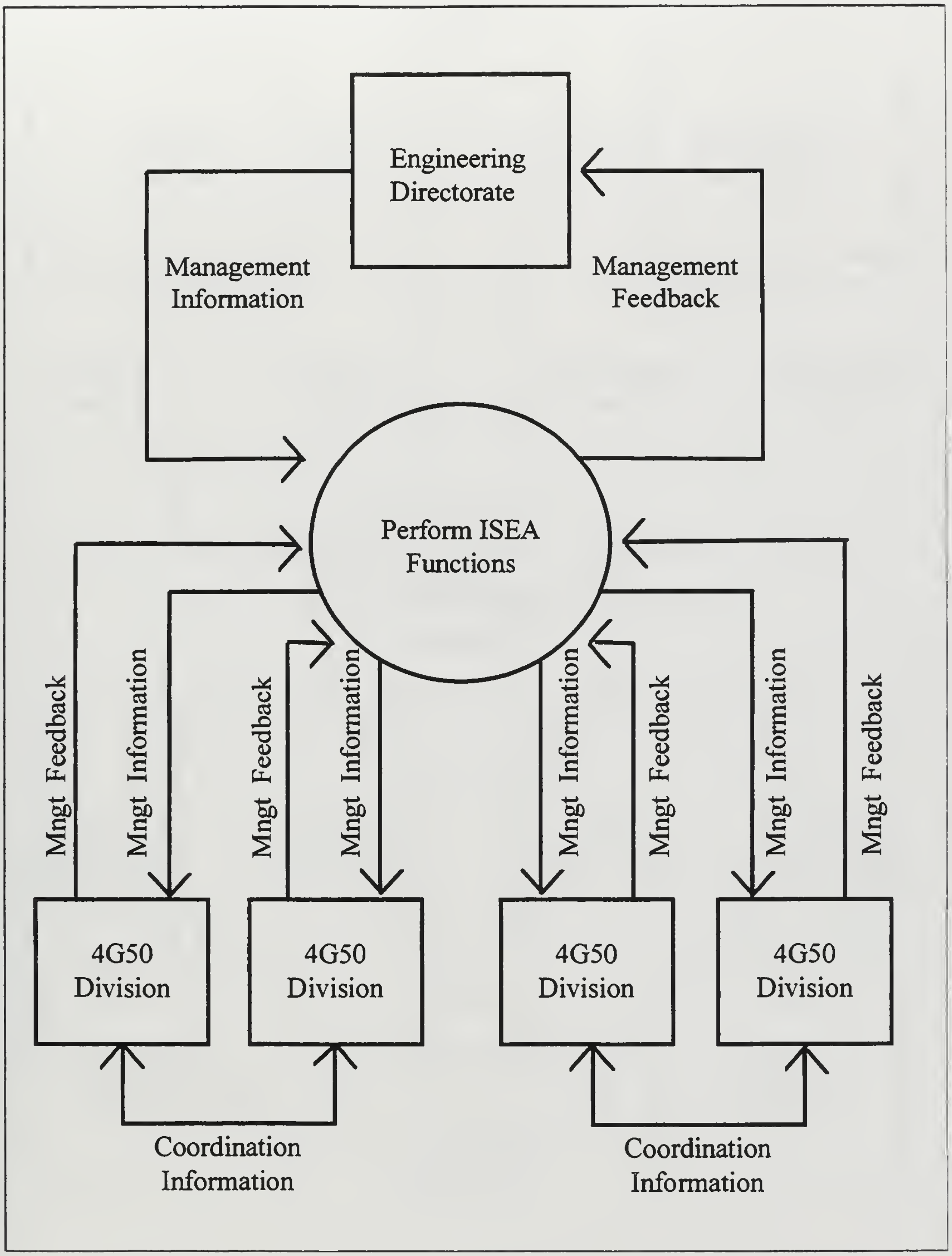


**Figure 15. Information Flows (CWD Perspective -- View Three)**

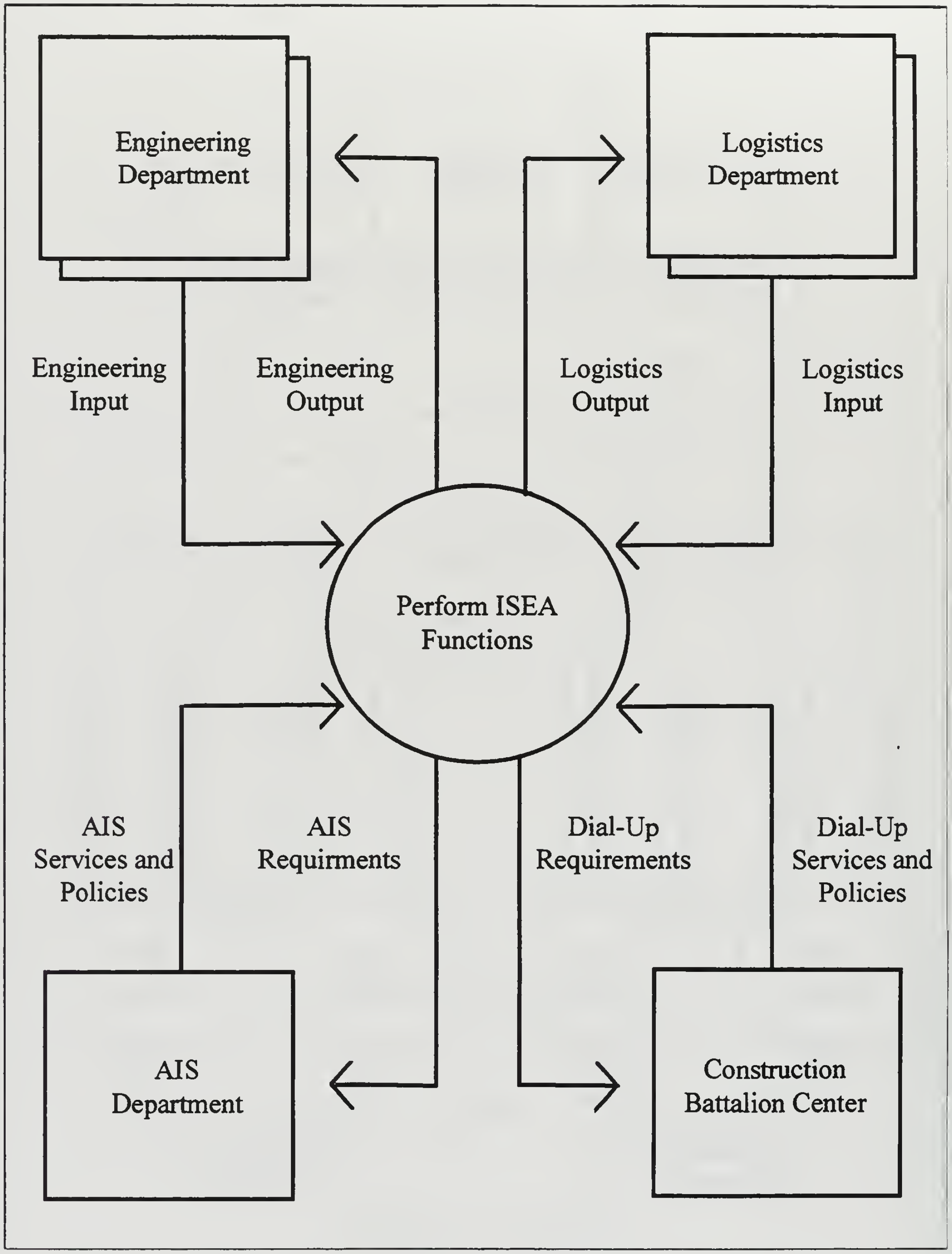


**Figure 16. Information Flows (CWD Perspective -- View Four)**

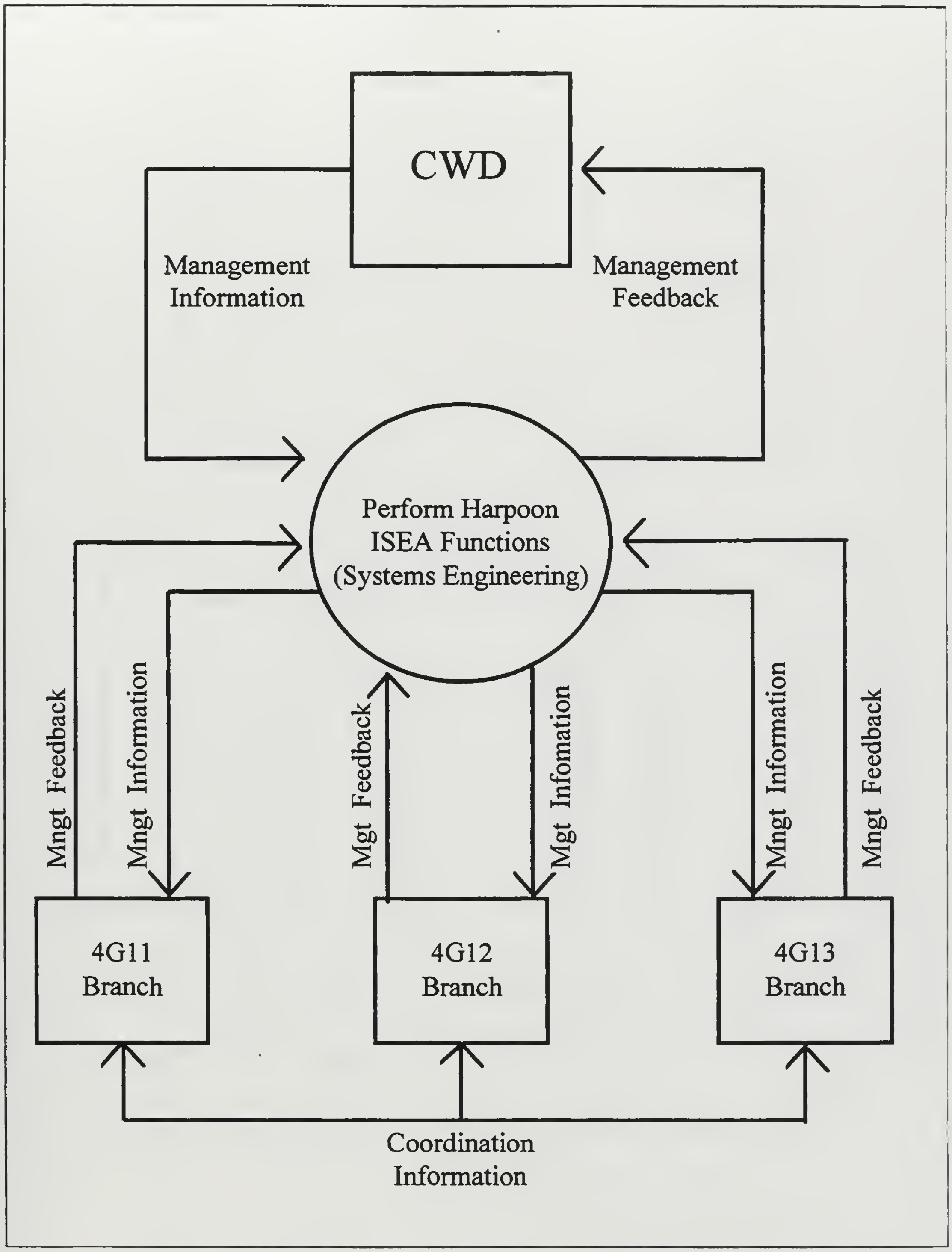


**Figure 17. Information Flows (4G10 Perspective)**

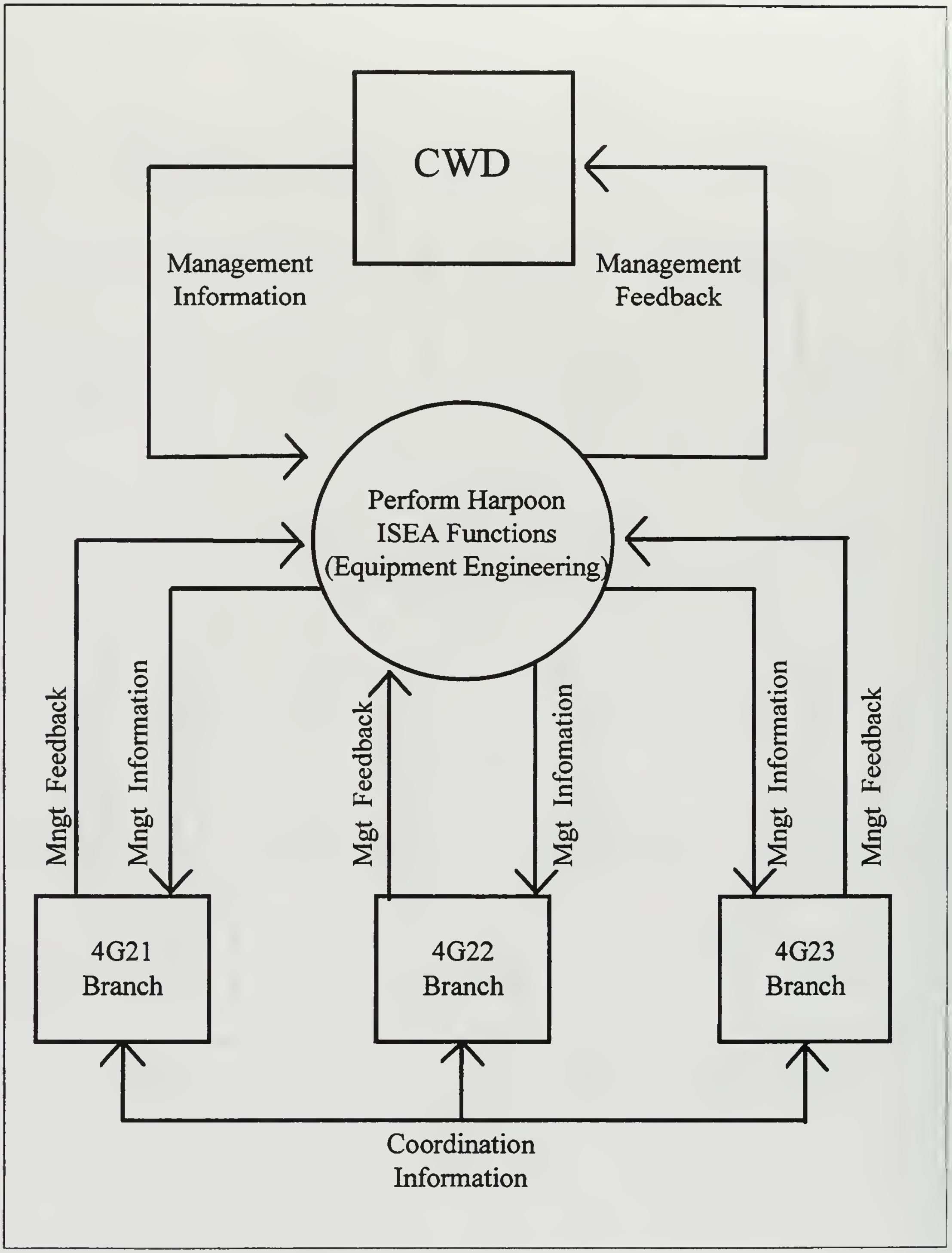


**Figure 18. Information Flows (4G20 Perspective)**

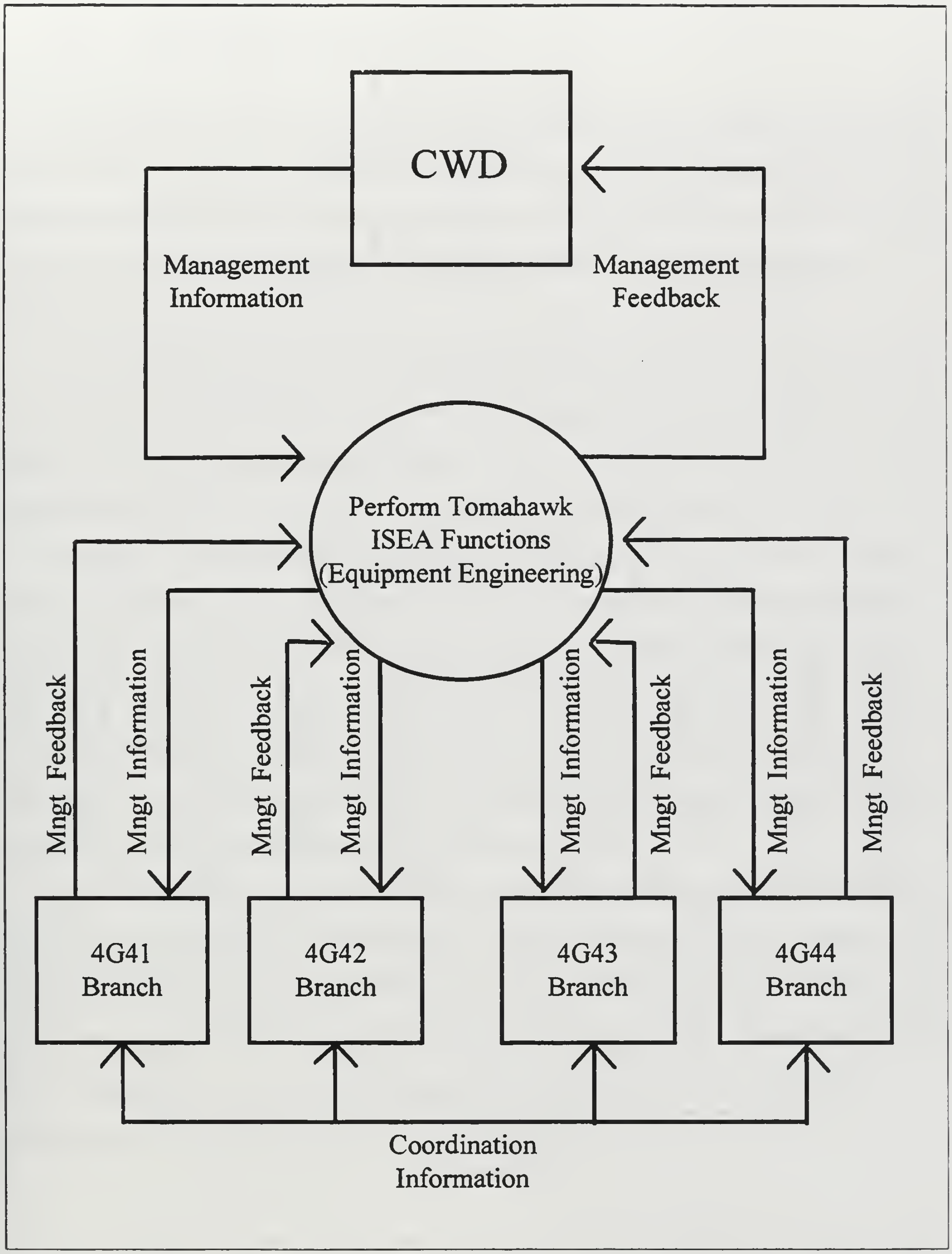


**Figure 19. Information Flows (4G40 Perspective)**

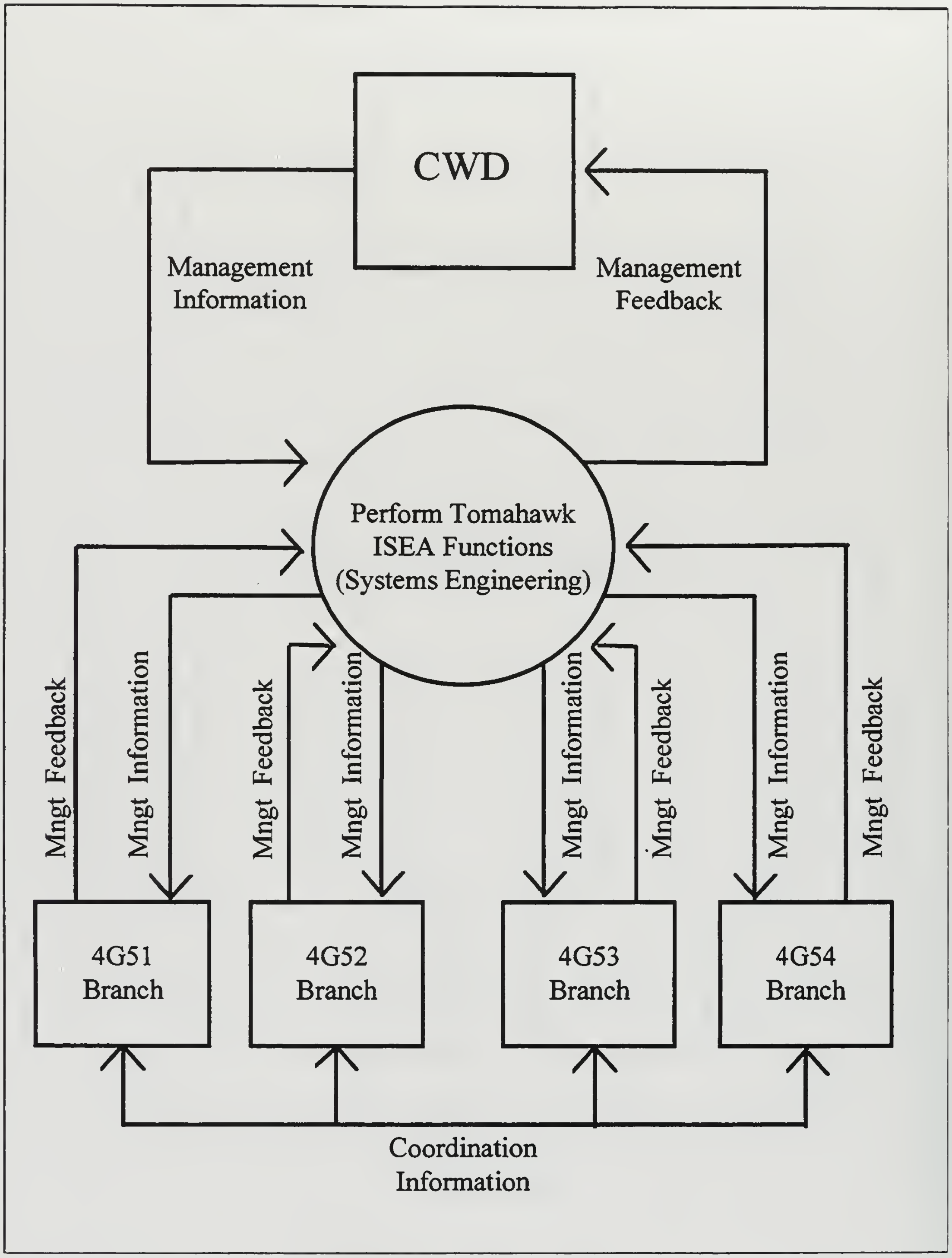


**Figure 20. Information Flows (4G50 Perspective)**

### 2. The Production Domain

The production domain contains the requirements, inputs, outputs, and feedback that flow between suppliers and CWD, and between CWD and customers. This flow of information is triggered by events in *each stage* of the production life cycle. This cycle encompasses planning, development, installation, maintenance, and configuration management.

In the planning phase, CWD deals primarily with top-level system requirements. These requirements are critical to the success of the program. Therefore, all the affected parties must hold and understand the current versions of them. The current versions are exchanged between CWD and its suppliers through the use of formatted documents.

During the first half of the development phase, CWD works with the segment, system, and interface design specifications. It also works with the actual component designs. In the second half, CWD deals with such items as final designs, engineering drawings, test plans and procedures, test reports, and performance data. This phase involves a great deal of communication among CWD, its suppliers, and its internal divisions.[5] Much of this communication is associated with the flow of data requests to the suppliers and the flow of data inputs to CWD. [Ref. 3]

During the installation phase, CWD is heavily involved in the preparation and delivery of technical manuals (TECHMANS), maintenance requirement cards (MRC's), Coordinated Shipboard Allowance List (COSAL) inputs, and other technical documents. These products are transmitted to ships and shore facilities. Most of these documents are sent in hard-copy format.[6] Some are recorded on compact discs and mailed to the customers for further distribution to the work centers.

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[5] For example, a supplier prepares a rough draft of a system specification document. This supplier sends the document to the entire development community. CWD, along with the rest of the community, reviews the document and sends feedback to the originator. The originator compiles the feedback and sends responses to the reviewers. When all of the outstanding issues are resolved, the originator produces a final draft and sends it to CWD as a data input.

[6] Via the Defense Publications and Printing Service Office or the Logistics Directorate (print on demand).

During the maintenance phase, customers transmit feedback to CWD. This feedback normally concerns problems with hardware, software, documentation, maintenance procedures, operating procedures, or logistics support. It may relate to a minor issue or a significant, time-critical problem. This information flows from the customers in the form of handwritten reports or Naval messages. It is processed by the Logistics Directorate[7] and passed to CWD for action.

In many cases, feedback reports trigger significant engineering and logistics changes. CWD works with the suppliers to ensure that the changes are made and documented. It modifies the engineering drawings and repair parts specifications and sends the new information to the Logistics Directorate. In addition, it updates the TECHMANS, MRC's, and COSAL inputs and sends the updated copies to the customers. Finally, CWD may, if the situation warrants, generate a technical bulletin and send it to the Fleet as a way of drawing special attention to a particular issue. [Ref. 6]

Configuration management does not exist as an independent phase. It is a continuous process that exists throughout the production life cycle. The Harpoon and Tomahawk systems are always changing. New components are added, and old ones are deleted or modified. New ships receive their installations, and older ships have their installations updated or removed. To track these events effectively, CWD must receive updates from designers, manufacturers, shipyards, and other key entities. It normally receives them through Naval messages, database records, and letters. After it receives the updates, CWD must modify its drawings, documents, and databases. Often, it will have to pass new information to its customers and peers. [Ref. 6]

In all phases of the life cycle, information flow from one or more external organizations to CWD. Within CWD, it flows to one or more divisions, one or more branches, and one or more individuals. Each of these entities plays a role in transforming the information so that CWD can pass it, as a product, to one or more external organizations. This complex flow pattern presents many challenges to CWD. For

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[7] Technical feedback reports can trigger widespread changes in the logistics support packages and their associated databases. Therefore, the Logistics Directorate serves as the single point of entry for all feedback reports entering the NSWC PHD domain.

example, the department must exercise version control over technical documents. In addition, the department must have a means for ensuring that the documents meet the schedule, cost, and quality goals established by the management team. These challenges are addressed by the information contained in the management and coordination domains.

### 3. The Management Domain

The management domain contains the information that flows between seniors and subordinates. This information is related to tasks, resources, and policies.

Task information is associated with development, maintenance, and special projects. Managers use this information to track schedule, cost, performance, and quality. They exchange it through E-mail, faxes, Naval messages, formatted documents, presentation graphics, letters, phone calls, and personal contacts. [Ref. 6]

Resource information is associated with people, money, facilities, equipment, and data. Managers use this information to evaluate needs, submit requirements, receive allocations, and control usage or consumption. They exchange it through E-mail, Naval messages, faxes, database reports, letters, phone calls, and personal contacts. [Ref. 6]

Policy information relates to such areas as organizational principles, personnel management, acquisition, and security. Seniors use this information to control the behavior of their subordinates. Subordinates use it to measure and report their levels of compliance. Policy information is normally exchanged through the use of Naval messages, letters, and personal contact. [Ref. 6]

The people who interact with the management domain must contend with multiple input and output streams as they attempt to supervise several tasks, control several resources, and comply with several policies simultaneously. They would benefit from a network that supports its simplification. [Ref. 12]

### 4. The Coordination Domain

The coordination domain contains the information that flows between peers. This information is related to production side-effects and support requirements.

CWD regularly adds, deletes, or modifies components of the Harpoon and Tomahawk weapon control systems. These actions can affect other systems[8] and lead to changes in logistics support packages. Therefore, CWD must keep the Systems Engineering and Logistics departments informed of any side-effects. By the same token, these departments must let CWD know when their efforts will affect the Harpoon or Tomahawk programs. This information is exchanged through E-mail, drawings, formatted documents, database records, and phone calls, and personal contacts. [Ref. 6]

In order to function effectively, CWD needs AIS and telecommunications support. To obtain this support, CWD gives the AIS Department and CBC information regarding its requirements. These entities respond with information regarding the services they will provide and the rules associated with using these services. CWD evaluates the level of support on a continuous basis. When its needs change, CWD gives the AIS Department and CBC new information regarding its requirements. This information is normally exchanged through E-mail, letters, phone calls, and personal contacts.

The coordination domain is complex. The people who interact with it must contend with multiple inputs and outputs, a web of interrelated engineering and logistics events, and the requirement to evaluate support needs on a regular basis. They would benefit from a network that supports the simplification of this domain.

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[8] For example, the Harpoon weapon control system and the Mark 92 Fire Control System may contend for a limited amount of space and electrical power. Therefore, an increase in the physical or electrical "footprint" of the Harpoon weapon control system can lead to a decrease in the space available for Mark 92.

### 5. Information Summary

Our study of the information resources allowed us to draw the following conclusions:

1. CWD's information resources exist in three domains: production, management, and coordination.
2. Production information relates to requirements, inputs, outputs, and feedback. This information passes between suppliers and CWD and between CWD and customers during each phase of the production life cycle.
3. Management information relates to tasks, resources, and policies. This information flows vertically between seniors and subordinates.
4. Coordination information relates to production side-effects and support requirements. This information flows horizontally between peers.
5. The information in these domains can reside in E-mail, Naval messages, faxes, multi-version documents, engineering drawings, database records, letters, phone calls, and personal contacts.

## D. BASELINE APPLICATIONS

### 1. Introduction

CWD produces, manages, and coordinates. In order to perform these functions effectively, CWD must have the proper tools. In the factory model, these tools would be drill presses, lathes, calendars, and time cards. In the world of computer networking, they are the *applications* used by the organization to process information.

We used a three-step process to study CWD's applications suite. We started by examining the production, management, and coordination functions in detail. From this examination, we identified the capabilities that *should* be supported by the applications suite. Then, we matched the elements of the current suite against the capabilities they support. By so doing, we were able to determine *what* applications need to be supported by the network and *why* the network needs to support them.

### 2. Functional Decomposition

Figures 21 through 23 are functional decomposition diagrams. These describe the functions that must be performed in order for CWD to produce, manage, and coordinate effectively. By studying these diagrams, we can learn the following lessons:

1. <u>Production</u> has four sub-functions: input handling, input transformation, output delivery, and feedback handling.

2. Input handling involves determining data requirements, transmitting requirements to suppliers, receiving data inputs from suppliers, determining the routing of inputs, and then routing inputs to the appropriate divisions, branches, and individuals.

3. Input transformation involves reviewing inputs, correcting problems,[9] compiling inputs,[10] constructing a rough draft, reviewing and revising the rough draft, and constructing a final product.[11] *Output delivery* involves routing the product to the appropriate customers. *Feedback handling* involves receiving customer inputs and using the inputs to reassess data requirements.

4. Management has three sub-functions: task management, resource management, and policy management.

5. Task management involves organizing, planning, and controlling development, maintenance, and special projects.

6. Resource management involves supervising, administering, and controlling people, money, facilities, equipment, and data.

7. Policy management involves formulating, promulgating, and enforcing policies.

8. Coordination has two sub-functions: external coordination and internal coordination.

9. External coordination involves working with peers and service providers.

10. Internal coordination involves allowing divisions, branches, and individuals to work with each other.

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[9] This can be as simple as editing a document in-place or as complex as working with several suppliers to resolve an outstanding design issue.

[10] This can be as simple as merging two pieces of plain text or as complex as building a single document from a collection of schematics, illustrations, charts, and formatted text.

[11] By the time a final product is ready for publication, it may have passed through several branches, divisions, and external organizations.

- **HANDLE INPUTS**
  - Determine data requirements
  - Transmit data requirements
  - Receive data inputs
  - Determine routing of inputs
  - Route inputs
- **TRANSFORM INPUTS**
  - Review inputs
  - Correct problems
  - Compile inputs
  - Construct rough draft
  - Review and revise rough draft
  - Construct final draft
- **DELIVER OUTPUTS**
  - Determine routing
  - Transmit final draft
- **HANDLE FEEDBACK**
  - Receive feedback from Customers
  - Reassess data requirements

**Figure 21. Functional Decomposition (Production)**

**MANAGE TASKS**
- Manage Development Projects
- Manage Support Projects
- Manage Special Projects

**MANAGE RESOURCES**
- Manage People
- Manage Money
- Manage Facilities
- Manage Equipment
- Manage Data

**MANAGE POLICIES**
- Formulate Policies
- Promulgate Policies
- Enforce Policies

**Figure 22. Functional Decomposition (Management)**

**COORDINATE EXTERNALLY**
- Coordinate with Peers
- Coordinate with Service Providers

**COORDINATE INTERNALLY**
- Coordinate between Divisions
- Coordinate between Branches
- Coordinate between Individuals

**Figure 23. Functional Decomposition (Coordination)**

### 3. Application Requirements

Production materials typically exist as documents, drawings, or database records. In order to handle these materials effectively, CWD needs workgroup-oriented applications that provide document, drawing, and database management capabilities. The document managers must support the creation, exchange, review, editing, and publication of multi-version documents. The drawing managers must allow users to create, exchange, review, edit, and publish multi-version drawings. Finally, the database managers must help users enter, view, manipulate, and delete database records.

Management materials normally exist as simple messages, presentation graphics, project management documents, resource management documents, and letters. In order to handle these materials effectively, CWD needs workgroup-oriented applications that provide messaging, presentation, project management, resource management, and document management capabilities. The messaging systems must enable the exchange of simple messages and formatted documents. The presentation tools must support the production, display, and exchange of presentation graphics. The project managers must help users control and monitor distributed projects. The resource managers must help users control and monitor people, money, facilities, equipment, and data. Finally, the document managers must provide facilities for creating, exchanging, reviewing, and editing correspondence.

CWD's coordination materials normally exist as simple messages and letters. In order to handle these materials properly, CWD must have workgroup-oriented application that provide messaging and document management capabilities. These systems must support coordination in the same fundamental way that they support management.

In summary, CWD cannot function effectively without applications that provide database management, document management, drawing management, messaging, presentation, project management, and resource management capabilities.

### 4. Current Applications Suite

CWD's has a complex applications suite. This suite *partially satisfies* the department's requirements. Its key members include:

1. *Autocad*, a *Unix* application that satisfies some of CWD's drawing management requirements [Ref. 20]
2. *Cc:Mail*, an application that works with *Windows, DOS,* or *Unix* and satisfies some of the Cruise Weapons community's messaging and document management requirements [Ref. 19]
3. *Draw*, a *Windows* application that satisfies some of CWD's drawing management requirements [Ref. 17]
4. *Electronic Data Network* (EDN), a *Unix* application that satisfies some of the Cruise Weapons community's document management requirements [Ref. 21]
5. *Interleaf*, a *Unix* application that satisfies some of CWD's document management requirements. [Ref. 20]
6. *Joint Computer-Aided Acquisition and Logistics System* (JCALS), a *Unix* application that may become a standard within DoD (CWD uses it to a limited extent to satisfy document management requirements) [Ref. 6]
7. *Joint Engineering Drawing Management and Information Control System* (*JEDMICS*) a *VMS* application that may become a standard within DoD (CWD has made some use of *JEDMICS* to satisfy drawing management requirements, but it continues to rely on 35mm aperture cards to store and retrieve most engineering drawings) [Ref. 6]
8. *Mosaic*, a *Unix* application that meets some of CWD's document management requirements [Ref. 20]

9. *Novix*, a *Windows* application that helps CWD provide access to database management and document management applications [Ref. 17]

10. *Office*, a *Windows* application suite that satisfies some of the Cruise Weapons community's document management, presentation, and project management requirements [Ref. 6]

11. *Open Mail*, a *Unix* application that satisfies some of NSWC PHD's messaging requirements [Ref. 20]

12. *Project*, a *Windows* application that satisfies some of the Cruise Weapons community's project management requirements [Ref. 4]

13. *Quicken*, a *Windows* application that satisfies some of CWD's resource management requirements [Ref. 17]

14. *RBase*, a *DOS* application that satisfies some of CWD's resource management and document management requirements [Ref. 6]

15. *Sun Mail*, a *Unix* application that satisfies some of CWD's messaging requirements. [Ref. 20]

16. *Tomahawk Engineering Exchange Network* (TEXN), a *DOS* application that satisfies some of the Tomahawk community's database management, project management, and resource management requirements [Ref. 13]

17. *Tomahawk Information System* (TOMIS), a *Unix* application that satisfies some of the Tomahawk community's database management requirements [Ref. 4]

18. *Track Message*, a proprietary, *DOS*-based application that satisfies some of NSWC PHD's messaging requirements [Ref. 9]

19. *WordPerfect*, a *Windows*-based or *Unix*-based application that satisfies some of CWD's document management requirements [Ref. 6]

### 5. Applications versus Requirements

Table 1 compares the applications and the requirements they support (a shaded square indicates that the application partially satisfies the requirement). By examining this table, we can discover that there are no unjustified applications or unaddressed requirements. At the same time, we should realize that there are overlapping capabilities (*e.g.,* Several applications perform document management functions.) and inadequately supported functions (*e.g.,* None of the document managers provide an adequate means for controlling the flow of multi-version documents within a large workgroup [Ref. 6]).

| | Database | Document | Drawing | Message | Present | Project | Resource |
|---|---|---|---|---|---|---|---|
| **Autocad** | | | ■ | | | | |
| **Cc:Mail** | | ■ | | ■ | | | |
| **Draw** | | | ■ | | | | |
| **EDN** | | ■ | | | | | |
| **Interleaf** | | ■ | | | | | |
| **JCALS** | | ■ | | | | | |
| **JEDMCIS** | | | ■ | | | | |
| **Mosaic** | | ■ | | | | | |
| **Novix** | ■ | ■ | | | | | |
| **Office** | | ■ | | | ■ | ■ | |
| **Open Mail** | | | | ■ | | | |
| **Project** | | | | | | ■ | |
| **Quicken** | | | | | | | ■ |
| **RBase** | | ■ | | | | | ■ |
| **Sun Mail** | | | | ■ | | | |
| **TEXN** | ■ | | | | | ■ | ■ |
| **TOMIS** | ■ | | | | | | |
| **Track Msg** | | | | ■ | | | |
| **WordPerf** | | ■ | | | | | |

**Table 1. Applications and the Requirements they Support**

### 6. Applications Summary

Our study of the applications suite allowed us to draw the following conclusions:

1. To perform its production, management, and coordination functions effectively, CWD must have applications that provide database management, document management, drawing management, messaging, presentation, project management, and resource management capabilities.

2. CWD's applications suite provides some of the required capabilities. This complex suite has nineteen key members. Some of the members work with *Windows* or *DOS*, while others work with *Unix* or *VMS*. Some are standards within the Cruise Weapons community or NSWC PHD. Others are potential standards within DoD, but many are unique to CWD.

## E. CONCLUSIONS

During our examination of the environment, we studied the key characteristics of the work organization, information, and applications. After reviewing these characteristics, we derived a set of seven top-level requirements for CWD's computer network. In the remainder of this section, we will summarize each of these requirements.

### 1. Requirement One (Entities)

The network must support the production, management, and coordination relationships that exist between CWD and the following entities:

1. AIS Department
2. CBC
3. Harpoon and Tomahawk Customers
4. Harpoon and Tomahawk Suppliers
5. Internal Divisions and Branches
6. NSWC PHD
7. NSWC PHD's Logistics Departments
8. NSWC PHD's Systems Engineering Directorate and Departments
9. PMA-282

### 2. Requirement Two (Geography)

To support the relationships that exist among key entities, the network must provide the means to pass information to and from the following areas:

1. Bahrain (Manama)
2. California (Long Beach, Port Hueneme, San Diego)
3. District of Columbia (Washington)
4. Florida (Mayport)
5. Hawaii (Pearl Harbor)
6. Italy (Gaeta)
7. Japan (Yokosuka)
8. Louisiana (Avondale)
9. Maine (Bath)
10. Mississippi (Pascagoula)
11. Missouri (Saint Louis)
12. Oceans (Atlantic, Indian, Pacific) and adjacent seas
13. Pennsylvania (Mechanicsburg)
14. Texas (Austin)
15. Virginia (Dahlgren, Norfolk)
16. Washington (Bremerton)

### 3. Requirement Three (Human Needs)

The network must meet the needs of people who interact with it. These individuals want the network to provide outstanding technical performance, offer stable and economical operations, adhere to the appropriate standards, support process improvement, and give technicians more time to devote to user support and professional development. In addition, they want the network to simplify the flow of information between remote sites and ease the maintenance and management burdens.

### 4. Requirement Four (Politics and Culture)

The network must help CWD balance its development and maintenance requirements, balance its sponsor and host requirements, achieve harmony with the AIS Department, maintain the integrity of the branch workgroups, support remote coordination between branch members, and establish a flexible operating environment.

### 5. Requirement Five (Flow of Information)

The network must support the simplified flow of production, management, and coordination information. The production information flows between CWD and its suppliers, and between CWD and its customers. The management information flows between CWD and its seniors, between CWD and its divisions, and between the divisions and their branches. The coordination information flows between CWD and its peers, between the Harpoon divisions and their branches, between the Tomahawk divisions and their branches, and within each branch.

### 6. Requirement Six (Exchange Media)

In order to support the three information domains effectively, the network must provide some means for using, replacing, or supplementing simple messages (Naval Messages, E-mail, faxes), multi-version documents, engineering drawings, database records, letters, phone calls, and personal contacts.

### 7. Requirement Seven (Applications)

The network must support applications with database management, document management, drawing management, messaging, presentation, project management, and resource management capabilities. In the current environment, these capabilities are partially provided by a complex applications suite. Each of the programs in this suite requires some degree of network support. These programs include:

1. *DOS* applications that are standards within the Cruise Weapons Community (*cc:Mail, TEXN)*
2. *DOS* applications that are standards within NSWC PHD (*Track Message*)
3. *DOS* applications that are unique to CWD (*RBase*)
4. *Unix* applications are standards within the Cruise Weapons Community (*cc:Mail, EDN, TOMIS*)
5. *Unix* applications that are standards within *NSWC PHD* (*Open Mail*)
6. *Unix* applications that may become standards within DoD (*JCALS*)
7. *Unix* applications that are unique to CWD (*Autocad*, *Interleaf, Mosaic, Sun Mail, Word Perfect*)
8. *VMS* applications that may become standards within DoD (*JEDMICS*)
9. *Windows* applications that are standards within the Cruise Weapons Community (*cc:Mail*, *Office, Project*)
10. *Windows* applications that are unique to CWD (*Draw*, *Novix, Quicken, WordPerfect*)

# IV. BASELINE NETWORK

## A. INTRODUCTION

CWD uses eight computer networks to help it perform its mission. This total includes one local area network (LAN), one backbone network, three dial-up networks, and three wide area networks (WAN's). In this phase of our project, we examined the key characteristics of these eight networks. Then, we looked at the top-level capabilities of the complete networking suite.

## B. LOCAL AREA NETWORK

### 1. The Heart of the Networking Suite

The heart of the networking suite is a 10 Mbps, Ethernet LAN. This LAN supports CWD, its internal divisions and branches, and some elements of the Logistics and Engineering directorates. It provides a logical and physical means for linking the department's computing resources. In addition, it serves as a pathway to the backbone.

### 2. Linked Resources

The resources linked by this LAN include two *NetWare* servers, three *Unix* servers, approximately 100 personal computers (PC's), five *Unix* workstations, 21 X-terminals, eleven printers, eight terminal servers, and a brouter.

The *NetWare* file servers are TIRS[1] and CW1. TIRS supports *cc:Mail*, while CW1 supports *Draw, Novix, Office, Project, Quicken, RBase,* and *Word Perfect*. [Ref.17]

The *Unix* file servers are Mercury, Phoenix and Athena. Mercury uses *SunOS*. It supports *Autocad, Interleaf,* and *Sun Mail*. Phoenix and Athena use *HP-VUE*. They support *Autocad, Interleaf, Mosaic, Open Mail,* and *Word Perfect*. [Ref. 20]

All of the PC's use *Windows* or *Windows for Workgroups*. Each PC has a network interface card (NIC) and a serial cable connection. The NIC provides 10 Mbps connectivity with the LAN, while the serial cable connection provides 19.2 kbps connectivity with a dial-up terminal server. [Ref. 17]

The *Unix* workstations run under *SunOS* or *Solaris*. One of the *SunOS* workstations is dedicated to *EDN*. It houses the *EDN* application software and the 14.4 kbps modem that provides connectivity with the EDN dial-up network. [Ref. 20]

The X-terminals are driven directly by Phoenix or Athena. They are the fastest (in terms of response time) platforms in the department. [Ref. 20]

The printers include eight *Laser Jets*, one *DeskJet*, a *Laser Writer*, and a *QMS* device. The most important of these is the *QMS*. This machine produces publication-quality documents in relatively high volume. It is maintained in a separate room and treated as a strategic asset. [Ref. 19]

The terminal servers give PC's access to NSWC PHD's modem pool (via the LAN and backbone). With these servers, PC's can use dial-up networks. [Ref. 17]

The brouter provides access to the backbone network. This device is actually a Cisco router. It has been configured, however, to function as a bridge.[2] [Ref. 18]

### 3. Forming the Network

The file servers, user nodes, terminal servers, printers, and brouter do not exist independently. They, instead, form a LAN. Figure 24 shows the logical view of the LAN, while Figure 25 shows the physical view.

From the logical perspective, the LAN has a bus topology. This bus provides places for the resources to attach themselves and initiate communications. Half of this bus supports the "*NetWare* subnetwork," a system consisting of TIRS, CW1, the PC's,

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[1] TIRS is an outdated acronym relating to the Tomahawk Installation and Check-Out Reporting System.

[2] AIS Department assigns IP addresses to all devices in the NSWC PHD campus. These addresses are assigned according to an administrative scheme that does not support logical subnetworking. Because of

the terminal servers, and some of the printers. The other half supports the "*Unix* subnetwork," a system consisting of Mercury, Phoenix, Athena, the *Unix* workstations, the X-terminals, and some of the printers. Between these halves is the brouter, the "gateway to the rest of the world."

From the physical perspective, the LAN has a cascaded star topology. This topology is formed by smart hubs, transmission media, the nodes, and the brouter. The smart hubs are at the center of each star. They provide a means for connecting nodes (file servers, PC's, X-terminals, *etc.*) to the network. This connection is made using Unshielded Twisted Pair (UTP) cabling (for 75% of the user nodes), Shielded Twisted Pair (STP) cabling (for 25% of the user nodes), or fiber optic cabling (for the file servers). The smart hubs are connected to each other using fiber optic cabling. One of the hubs is fiber-connected to the brouter and, by extension, the "rest of the world." [Ref. 18]

This LAN uses two communications protocol stacks. One is based on Novell's Sequenced Packet Exchange (SPX) and Internet Packet Exchange (IPX). The other is based on the Transmission Control Protocol (TCP) and Internet Protocol (IP). The SPX/IPX stack supports communications between the PC's and the *NetWare* file servers. The TCP/IP stack supports communications between the X-terminals and the *Unix* file servers, between the *Unix* workstations and *Unix* file servers, and between each file server and the brouter. [Ref. 19]

#### 4. Managing and Maintaining the Network

CWD has a support staff and some tools to help it manage and maintain the LAN. It does not, however, have the policies, procedures, or documentation needed to use these assets effectively. In addition, it does not have a network operations center to coordinate the daily management and maintenance efforts. As a result, the department faces two problems: (1) it does not provide adequate maintenance support to *today's* users, and (2) it is does not have the ability to deal with *tomorrow's* management problems effectively.

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this, the facility has not been able to establish a functional routing scheme. Therefore, none of the Cisco routers can function as routers. They must, instead, function as expensive bridges.

The support staff has eight members. One is responsible for managing and providing long-term direction. The others are responsible for maintaining components of the network.

Three of the maintenance specialists focus on file servers. One deals with TIRS. Another is responsible for CW1. A third handles Mercury, Phoenix, and Athena. These people are free to establish their own schedules and procedures. For example, the TIRS administrator follows a rigid schedule of back-ups and daily maintenance. This schedule includes 874 hours of planned "down time" each year [Ref. 19]. The CW1 administrator, on the other hand, does not place as much emphasis on back-ups and maintenance. His schedule includes only 130 hours of planned "down time" each year [Ref. 17]. At the other end of the spectrum, is the *Unix* system administrator. Her schedule does not include any time for regular maintenance [Ref. 20].

One of the specialists concentrates on the physical substrate. He works with cabling, the smart hubs, NIC's, terminal servers, and brouter. Because he is extremely familiar with the networking infrastructure, he has not felt the need to maintain detailed, current documentation showing the locations and purposes of each component. [Ref. 10]

The other specialists provide applications support. One person, for example, works with *EDN*. He is responsible for handling incoming tapes, loading them into the workstation, informing the appropriate reviewers, and facilitating the transfer of reviewers' comments to the originating agency. [Ref. 21]

CWD has a small number of tools to help the technicians manage and maintain the network. These tools include a protocol sniffer and a copy of HP's *OpenView for Windows*. The sniffer is used to monitor traffic utilization levels and pinpoint the sources of "broadcast storms." It receives its information from the management agents that reside in smart hubs, *Unix* workstations, and X-terminals. *OpenView* is an extremely capable tool. Unfortunately, it is installed on an older, 25 MHZ PC. This platform does not provide adequate support to the application. Therefore, the application is perceived as being "worthless" for anything other that producing network diagrams. [Ref. 18]

The department has people and tools, but it does not have a formal set of policies and procedures for integrating these assets effectively. There is no written direction

concerning back-up schedules, planned maintenance, corrective maintenance, cabling documentation, or tool usage. There is no guidance concerning *which* performance parameters to measure (*e.g.,* availability, response time, utilization level), *how* to measure them, or *when* to measure them. As a result, CWD is not prepared to deal effectively with tomorrow's management problems. For example, it is not ready to face the retirement or departure of its current technicians, and it is not ready for the day when the network's complexity overcomes the informal maintenance "system."

The department does not have a network operations center. There is no centralized organization to oversee maintenance schedules, coordinate troubleshooting, prioritize work requests, provide help, or update the status of the network. As a result, CWD cannot provide adequate maintenance support to its user community or give its management team an accurate "snapshot" of the network's status [Ref. 6].

Finally, the department does not have a formal plan for training its technicians. CWD sends some personnel to courses (*e.g., NetWare* certification classes), but it does not include these courses in a regular programs of beginning, intermediate, advanced, and repetitive training. Because of this shortfall, technicians have difficulty maintaining proficiency and keeping pace with the rapid changes in information technology. [Ref. 19]

### 5. LAN Summary

Our study of the LAN allowed us to draw the following conclusions:

1. CWD operates a 10 Mbps, Ethernet LAN that uses a mixture of UTP, STP, and fiber optic cabling. This network has a logical bus topology and a physical star topology. It uses SPX/IPX and TCP/IP communications protocols.

2. This LAN supports CWD, its internal divisions and branches, some Logistics departments, and some Engineering departments.

3. This LAN supports five file servers. These server provide access to several *Windows, DOS,* and *Unix* applications.

4. This LAN supports about 130 user nodes. These nodes run under the *Windows, Windows for Workgroups, SunOS, Solaris,* and *HP-VUE* operating environments.

5. The LAN supports eleven printers. The most important of these is *QMS*, a device that produces publication-quality documents for the department.

6. This LAN supports eight terminal servers and a brouter. The terminal servers provide access to dial-up networks. The brouter provides access to the backbone.

7. CWD has a small support staff and a handful of tools to help it manage the LAN. It does not, however, have the policies, procedures, organizational structures, or training programs needed to use these assets effectively. As a result, the department does not provide adequate maintenance support to its users, and it does not have the ability to deal with tomorrow's management problems effectively.

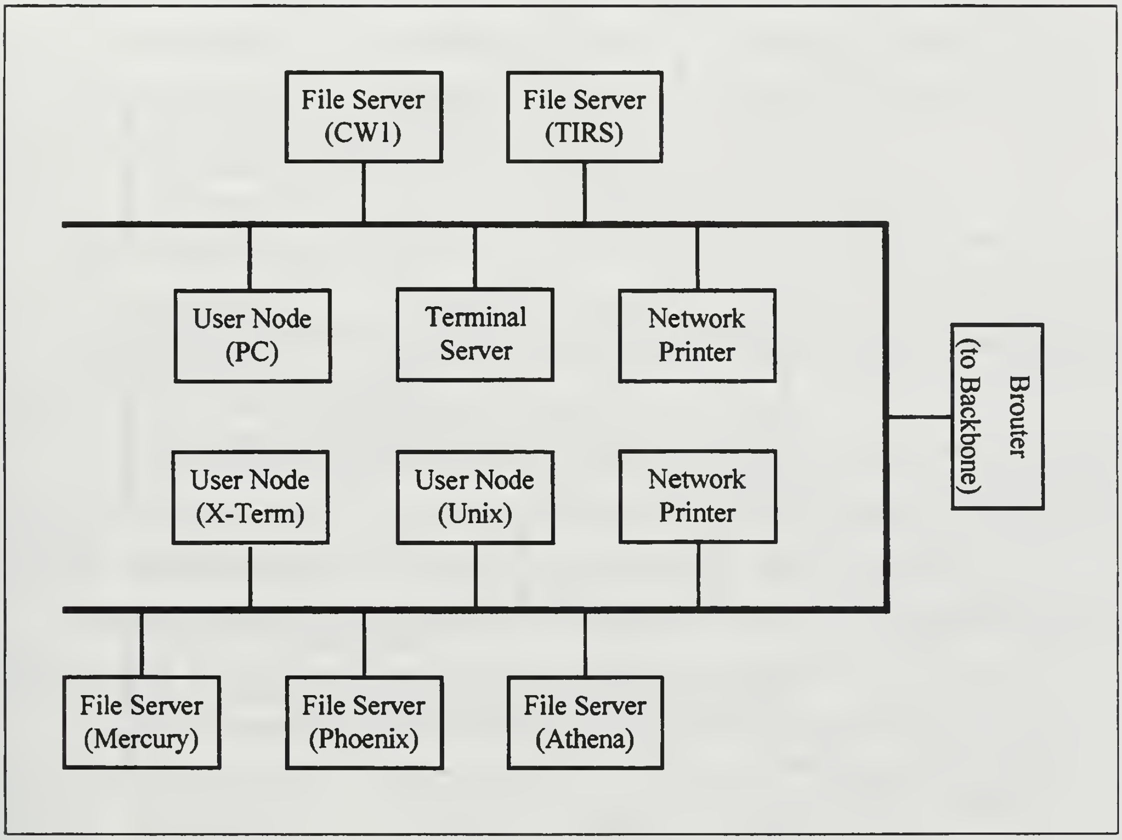


**Figure 24. Local Area Network (Logical View)**

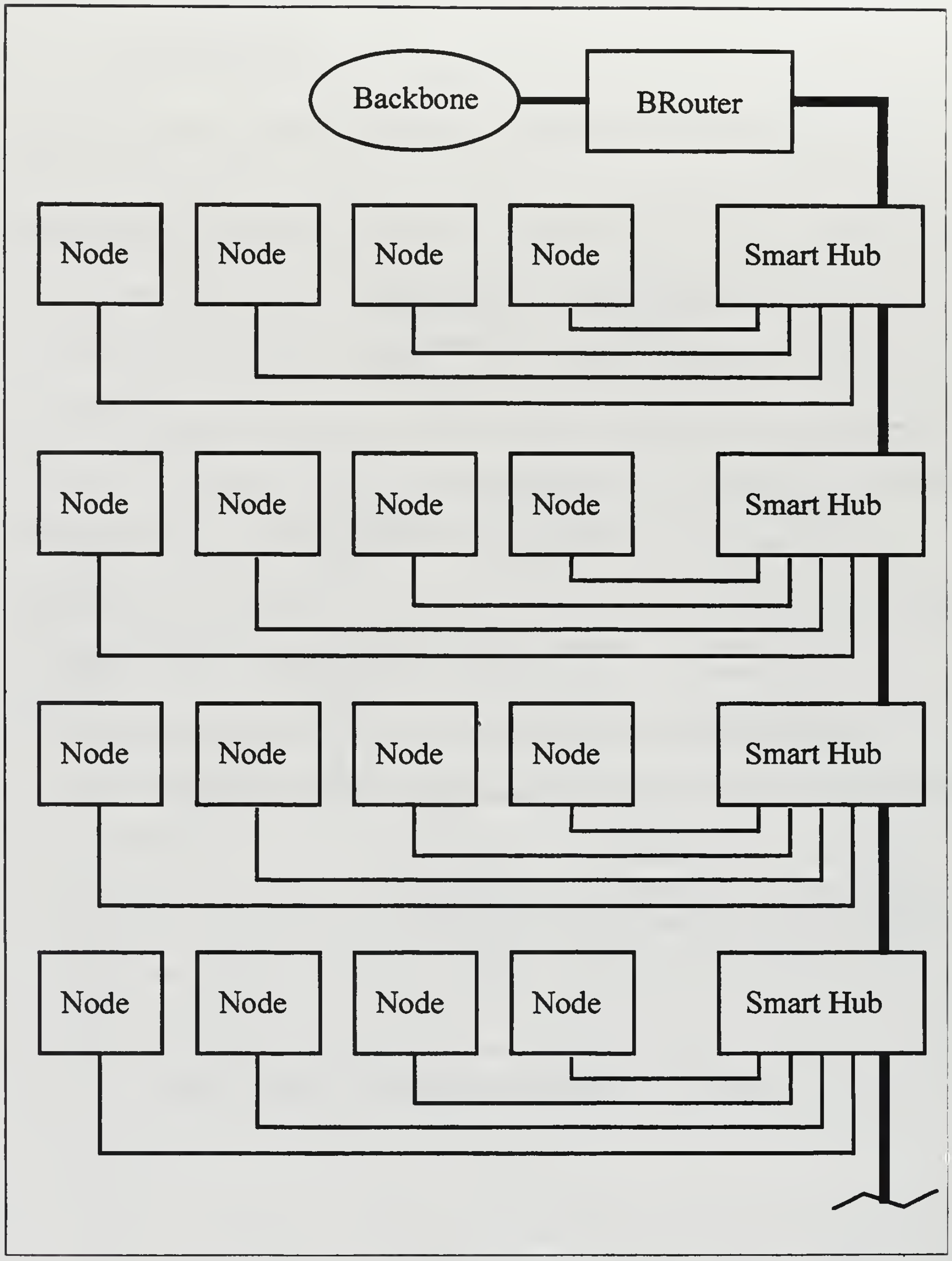


**Figure 25. Local Area Network (Physical View)**

## C. BACKBONE NETWORK

### 1. Serving NSWC PHD

The AIS Department operates a 10 Mbps, Ethernet backbone. This network supports NSWC PHD, its Engineering departments, its Logistics departments, and CBC. It provides a logical and physical means for linking NSWC PHD's computing resources. In addition, it servers as a pathway to the dial-up networks and WAN's.

### 2. Linked Resources

The resources linked by this backbone include Engineering LAN's, Logistics user nodes, a terminal server, and a router.

Most of the Engineering departments have their own LAN's. Some of them have followed CWD's lead and used a configuration that mixes *NetWare* and *Unix* file servers. Others have chosen to abandon *NetWare* in favor of *Windows NT*. [Ref. 22]

The Logistics departments do not have their own LAN's. They, instead, use Sun workstations or PC's that are directly attached to the backbone network. [Ref. 18]

The terminal server works with the departments' terminal servers to provide access to the modem pool. With this server, PC's can use several dial-up networks. [Ref. 17]

The router links NSWC PHD to a second router in Point Mugu (California) and a third router in Monterey (California).[3] The Point Mugu router provides access to the Navy Network (DISN/NAVNET-IP) and the Military Network (MILNET). The Monterey router provides access to the Defense Research and Engineering Network (DREN). [Ref. 15]

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[3] It also provides direct access to the Naval Sea Systems Command Enterprise-Wide Network (NEWNET). CWD does not use this network extensively. Therefore, it is not covered in this report.

### 3. Forming the Network

The Engineering LAN's, Logistics user nodes, terminal server, and router do not exist independently. They, instead, form a backbone network. Figure 26 shows the logical view of the backbone, while Figure 27 shows the physical view.

From the logical perspective, this network has a bus topology. This bus provides places for resources to attach themselves and initiate communications.

From the physical perspective, this network has a cascaded star topology. This topology is formed by Cisco brouters, transmission media, smart hubs, the terminal server, and the router. The brouters are at the center of each star. They support a single building by providing a means for connecting each building's smart hubs to the network. In most cases, this connection is made using fiber optic cabling. The brouters are connected to each other using buried fiber optic cabling. One of the brouters is connected (via a smart hub) to the terminal server and routers. These devices provide the physical pathway to the "outside world." [Ref. 18]

This backbone uses the TCP/IP protocol stack to support communications between its nodes and to support communications with the WAN's. [Ref. 18]

### 4. Evaluating the Network

Unfortunately, the backbone network does not provide adequate performance, manageability, or maintainability. It is slow [Ref. 23], congested [Ref. 20], and subject to frequent failures [Ref. 18]. Its IP address allocation scheme does not support subnetworking and, as a result , contributes to the performance problems [Ref. 18]. It does not have a network operations center, a formal maintenance program, a method for prioritizing troubleshooting tasks, or a training plan [Ref. 23]. The cabling plant is neither labeled nor documented [Ref. 23]. Finally, the wiring closets are unventilated, unsecured, and poorly lit [Ref. 23]. Because of these problems, CWD is not confident about the backbone's long-term ability to support its networking requirements [Ref. 18].

### 5. Backbone Summary

Our study of the backbone network allowed us to draw the following conclusions:

1. The AIS Department operates a 10 Mbps, Ethernet backbone that uses fiber optic cabling. This network has a logical bus topology and a physical star topology. It uses TCP/IP communications protocols.
2. This backbone supports NSWC PHD, its Engineering departments, its Logistics departments, and CBC.
3. This backbone supports a terminal server and a router. The terminal server provides access to dial-up networks. The router provides access to the WAN's.
4. The backbone does not provide adequate performance, maintainability, or manageability. As a result, it may not be able to meet CWD's long-term requirements.

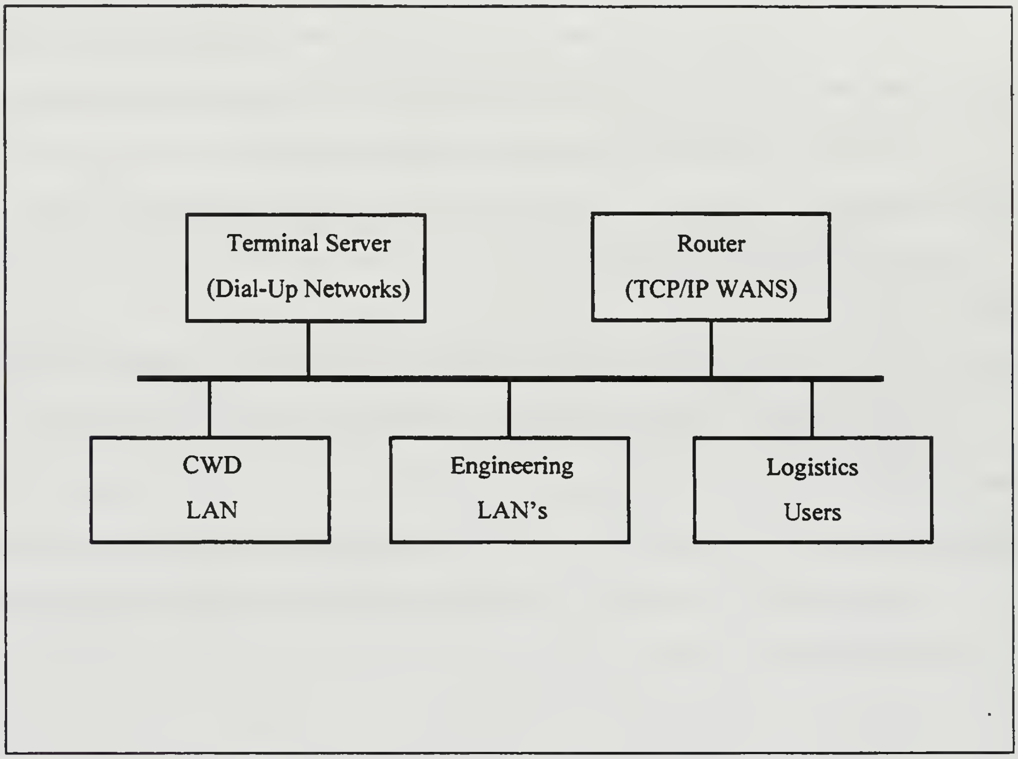


**Figure 26. Backbone Network (Logical View)**

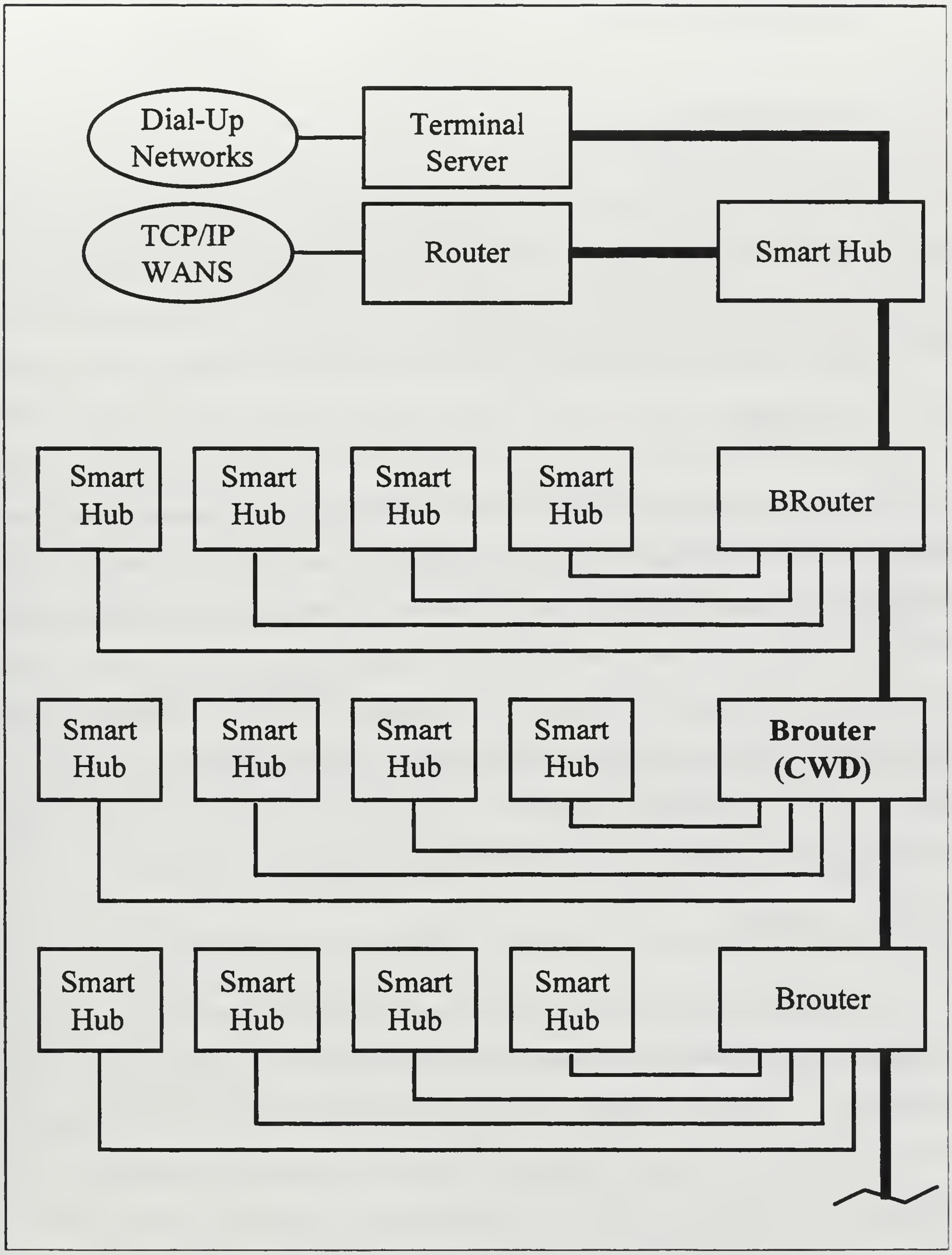


**Figure 27. Backbone Network (Physical View)**

## D. DIAL-UP NETWORKS

### 1. Overview

CWD uses several single-purpose, dial-up networks to help it perform its mission. The most important of these are the Tomahawk Engineering Exchange Network (TEXN), the Electronic Data Network (EDN), and the *cc:Mail* network. Figure 28 shows the physical relationships between these networks and the rest of the suite.

### 2. TEXN

TEXN is a hub-and-spoke network that gives users access to a central database (maintained in Saint Louis, Missouri). This network is managed by TWCS-SEIA. Its primary users include CWD's Tomahawk divisions and branches, SCCI, NSWC DD, TWCS-SEIA, shipyards, some operational staffs, and PMA-282. These users are located in California (Long Beach, Port Hueneme, San Diego), the District of Columbia, Hawaii (Pearl Harbor), Louisiana (Avondale), Maine (Bath), Missouri (Saint Louis), Texas (Austin), and Virginia (Dahlgren, Norfolk). All of them access TEXN through relatively slow and unreliable 9.6 kbps, dial-up connections. [Ref. 13]

### 3. EDN

EDN is a mesh network that gives its users that ability to exchange formatted documents. This network is loosely managed by NSWC DD (Dahlgren) with the help of SCCI (Austin). Its primary users include CWD's Tomahawk divisions and branches, SCCI, LAO, NSWC DD, TWCS-SEIA, and PMA-282. These users are located in California (Port Hueneme), the District of Columbia, Missouri (Saint Louis), Texas (Austin), and Virginia (Dahlgren). All of them access EDN through 14.4 kbps, dial-up connections. [Ref. 21]

### 4. CC:MAIL

The *cc:Mail* is a hub-and-spoke network that gives users access to the Saint Louis mail hub. By so doing, it supports the flow of E-mail and binary file attachments within the Tomahawk community. In addition, it gives users the ability to exchange E-mail with any recognizable *cc:Mail*, Simple Mail Transfer Protocol (SMTP) or X.400 address. This network is managed by TWCS-SEIA. Its primary users include CWD, Engineering and Logistics departments, SCCI, LAO, NSWC DD, TWCS-SEIA, PMA-282, tenders, training centers, some logistics commands, fleet activities, and one type command. These users are located in California (Port Hueneme, San Diego), the District of Columbia, Hawaii (Pearl Harbor), Japan (Yokosuka), Missouri (Saint Louis), Texas (Austin), and Virginia (Dahlgren, Norfolk). Most of them access the *cc:Mail* network through 56 kbps, TCP/IP connections. CWD accesses it through a 28.8 kbps, dial-up connection. [Ref. 19]

### 5. Dial-Up Summary

Our study of the dial-up networks allowed us to draw the following conclusions:

1. CWD regularly uses three dial-up networks: TEXN, EDN, and *cc:Mail.*

2. TEXN gives its users the ability to use database records. CWD accesses this network through a 9.6 kbps connection.[4]

3. EDN gives its users the ability to exchange formatted documents. CWD accesses this network through a 14.4 kbps connection.

4. *Cc:Mail* gives its users the ability to exchange E-mail and binary file attachments. CWD accesses this network through a 28.8 kbps connection.

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[4] There are no near-term plans to upgrade the transmission rate of this connection.

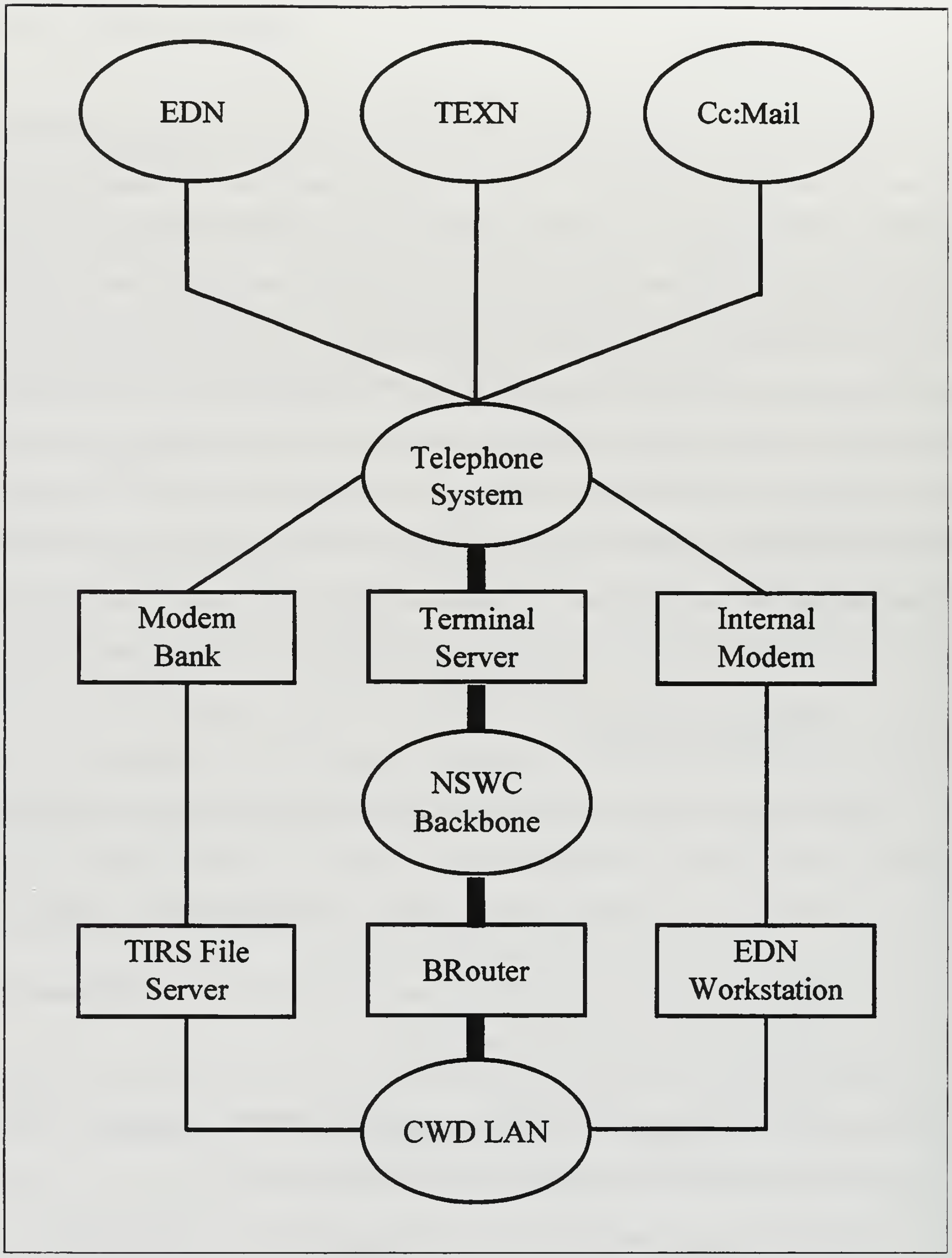


**Figure 28. Dial-Up Networks**

## E. WIDE AREA NETWORKS

### 1. Overview

CWD uses several multi-purpose TCP/IP WAN's to help it perform its mission. The most important of these are DISN/NAVNET-IP, MILNET, and DREN. Figure 29 shows the relationships between these networks and the rest of the suite.

### 2. DISN/NAVNET-IP

DISN/NAVNET-IP is a hybrid network that gives its users the ability to transfer files, exchange E-mail, conduct remote logins (including logins to *TOMIS*), and browse the World Wide Web (WWW) [Ref. 24]. This network is managed by the Naval Computers and Telecommunications Station in Pensacola, Florida [Ref. 24]. Its primary users include CWD, NSWC PHD, NSWC DD, PMA-282, logistics commands, training centers, type commands, and some operational staffs. These users are located in California (Port Hueneme, San Diego), the District of Columbia, Florida (Mayport), Hawaii (Pearl Harbor), Italy (Gaeta), Pennsylvania (Mechanicsburg), Virginia (Dahlgren, Norfolk), and Washington (Bremerton). CWD accesses DISN/NAVNET-IP through a fractional T-1 line that runs from NSWC PHD's router to Point Mugu's router. [Ref. 18]

### 3. MILNET

MILNET is a hybrid network that provides the ability to transfer files, exchange E-mail, conduct remote logins, and browse the WWW. In addition, it gives its users access to the global Internet.[5] This network is managed by the Defense Information Systems Agency (DISA) [Ref. 25]. Its primary users are shore-based DoD elements located in the United States, Europe, and Asia. CWD accesses MILNET through a 56 kbps line that runs from NSWC PHD's router to the Point Mugu router. [Ref. 18]

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[5] From CWD's perspective, the Internet access is the most important feature. With this access, the department can communicate with TWCS-SEIA and LAO (*N.B.*, SCCI is not an "Internet player.")

### 4. DREN

DREN is a hybrid network that gives its users the ability to transfer files, exchange E-mail, conduct remote logins, and browse the WWW. In addition, it supports distributed modeling and simulation applications. This network is managed by DISA. It is used by CWD, NSWC PHD, NSWC DD, and other research and engineering facilities [Ref. 26]. CWD accesses DREN through a T-1 line that runs from NSWC PHD's router to the Monterey router (operated by the Naval Civil Engineering Laboratory). [Ref. 18]

### 5. WAN Summary

Our study of the WAN's allowed us to draw the following conclusions:

1. CWD regularly uses three WAN's: DISN/NAVNET-IP, MILNET, and DREN. All of these networks give their users the ability to transfer files, exchange E-mail, conduct remote logins, and browse the WWW.
2. DISN/NAVENT-IP provides a means for communicating with Naval activities in the United States and Europe. In addition, it provides a means for using *TOMIS*. CWD accesses this network through a fractional T-1 line.
3. MILNET, through its Internet access point, provides a means for communicating with contractor organizations. CWD accesses this network through a 56 kbps line.
4. DREN provides a means for communicating with NSWC DD. CWD accesses this network through a T-1 line.

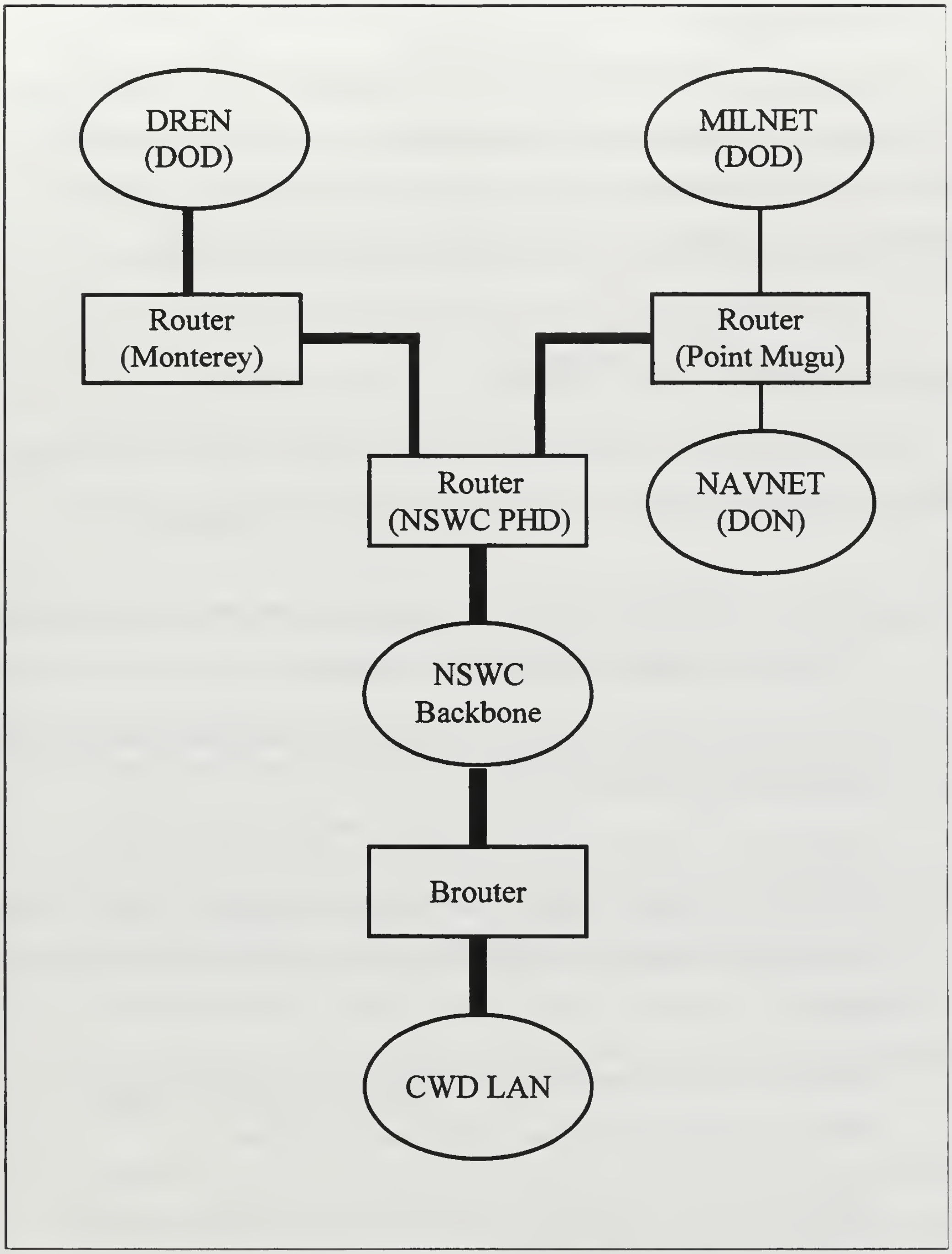


**Figure 29. Wide Area Networks**

## F. CAPABILITIES

The eight networks work together to form a complete suite. This suite gives CWD the ability to interconnect entities and geographic areas, meet human needs, contend with political and cultural factors, maintain information flows, replace or supplement various exchange media, and support functional applications.

### 1. Capability One (Entities)

The networking suite supports the production, management, and coordination relationships that exist between CWD and several internal and external entities.

1. Through the backbone network, it supports the coordination relationship that exists between CWD and the AIS Department.
2. Through the backbone network, it supports the coordination relationship that exists between CWD and CBC.
3. Through the *cc:Mail* network and TEXN, it supports the production relationships that exist between CWD and some customers (tenders, training centers, some logistics commands, one type command, and some operational staffs).
4. Through the dial-up networks and WAN's, it supports the production relationships that exist between CWD and its suppliers.
5. Through the LAN, it supports the management relationships that exist between CWD and its internal divisions, and between the internal divisions and their branches. In addition, it supports the coordination relationships that exist between the two Harpoon divisions, between the two Tomahawk divisions, between each division's branches, and within each branch.

6. Through the LAN and backbone, it supports the coordination relationships that exist between CWD and the Logistics departments.
7. Through the backbone, it supports the management relationship that exists between CWD and the Systems Engineering Directorate.
8. Through the LAN and backbone, it supports the coordination relationships that exist between CWD and the Systems Engineering departments.
9. Through the dial-up networks, it supports the management relationship that exists between CWD and PMA-282.

### 2. Capability Two (Geography)

To support the relationships that exist among key entities, the networking suite provides the means to pass information to and from several geographic areas.

1. Through the LAN and backbone, it provides the means to pass information within the Port Hueneme facility.
2. Through the dial-up networks, it provides the means to pass information to and from California (Long Beach, San Diego), the District of Columbia, Hawaii (Pearl Harbor), Japan (Yokosuka), Louisiana (Avondale), Maine (Bath), Mississippi (Pascagoula), Missouri (Saint Louis), Texas (Austin), and Virginia (Dahlgren, Norfolk).
3. Through the WAN's, it provides the means to pass information to and from California (San Diego), the District of Columbia, Florida (Mayport), Hawaii (Pearl Harbor), Italy (Gaeta), Japan (Yokosuka), Pennsylvania (Mechanicsburg), and Virginia (Dahlgren, Norfolk), and Washington (Bremerton).

### 3. Capability Three (Human Needs)

The networking suite meets some of the needs of the people who interact with it. Some elements provide good technical performance and economical operations while adhering to the appropriate standards.

1. Its file servers are reliable. TIRS is available 96.9% of the time [Ref. 19]. CW1 is available 98.4% of the time [Ref. 17]. Mercury, Phoenix, and Athena are available approximately 99.9% of the time [Ref. 20]. At these high levels, the department does not have to contend with excessive "down times."

2. Its LAN is not congested. During the typical workday, the LAN's utilization level ranges from 6.08% to 11.56%. These traffic loads are relatively low [Appendix A].

3. Its *cc:Mail* network provides good technical performance. During the typical workday, the department transmits 17 megabits of message data to the Saint Louis hub and receives 12 megabits from the hub. In its current configuration, the network can handle the entire day's load in less than three hours. This translates into excess capacity and near-term growth potential.[6] [Appendix B]

4. It offers economical operations. CWD spends approximately $821,000 per year operating and maintaining the LAN. This equates to $6000 per user node, a figure well below the national "planning range" of $8000 to $18,000. [Appendix C]

5. It adheres to the appropriate standards. The suite supports the Cruise Weapons community's standard applications. In addition, it uses TCP/IP, the

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[6] Unfortunately, it does not translate into long-term growth potential. By studying the 1995 usage and performance data, we can conclude that the demand for services is growing faster that the network's ability to provide those services. Without a significant change in configuration, the *cc:Mail* network will be unable to meet the department's anticipated requirements for 1998 and later years (See Appendix B for details).

*de facto* standard for wide area communications in DoD and DoN. Finally, its *cc:Mail* network supports SMTP, the *de facto* standard for E-mail in the United States, and X.400, the official standard in the international community.

#### 4. Capability Four (Politics and Culture)

The networking suite helps CWD deal with some of its political and cultural factors. Specifically, it provides some means for maintaining the integrity of branch workgroups, provides some means for supporting remote coordination between branch members, and provides for the establishment of a flexible operating environment.

1. It provides some means for maintaining the integrity of branch workgroups. Some branches use *Windows for Workgroups* on their networked PC's. With *Windows for Workgroups*, these branches have access to all LAN capabilities, <u>and</u> they can operate small, peer-to-peer networks that support the sharing of files, printers, and other resources. By sharing these resources, branch workgroups can function more effectively.
2. It provides some means for supporting remote coordination between branch members. Remote users can gain dial-in access to *cc:Mail*. This helps the distributed workgroups exchange simple messages and formatted documents.
3. It provides for the establishment of a flexible operating environment. The suite supports users nodes that run *Windows*, *Windows for Workgroups*, *MacOS, SunOS, HP-VUE,* and *X/Windows*. Users, therefore, have some freedom to choose an operating environment that meets their needs.

### 5. Capability Five (Flow of Information)

The networking suite supports the flows of production, management, and coordination information.

1. Through the dial-up networks, it supports the flow of production information between CWD and its suppliers.
2. Through the dial-up networks and backbone, it supports the flow of management information between CWD and its seniors.
3. Through the LAN, it supports the flow of management information between CWD and its internal divisions. It also supports the flow of management information between the internal divisions and their branches.
4. Through the LAN and backbone, it supports the flow of coordination information between CWD and its peers, between the Harpoon divisions and their branches, between the Tomahawk divisions and their branches, and within each branch.

### 6. Capability Six (Exchange Media)

In order to support the three information domains effectively, the networking suite provides the means for using, replacing, or supplementing E-mail, some multi-version documents, some engineering drawings, and database records.

1. By supporting *cc:Mail, Open Mail,* and *Sun Mail*, the suite gives users the ability to exchange E-mail with local and remote addresses.
2. By supporting word processing and messaging applications, the suite gives users the ability to produce and exchange *small*, multi-version documents (Users are still forced to transfer larger documents to magnetic tapes and then transfer the tapes through the postal system). It does not, however, support the

workflow management, version control, and quality control functions associated with these products.

3. By supporting drawing programs and messaging applications, the suite gives users the ability to produce and exchange *simple* drawings (Large, complex drawings are still handled through manual methods and 35mm aperture cards). It does not, however, support the version and quality control functions associated with these products.

4. By supporting database management and messaging applications, the suite gives users the ability to insert, edit, delete, and exchange database records.

### 7. Capability Seven (Applications)

The networking suite supports applications with database management, document management, messaging, presentation, project management, and resource management capabilities. These supported applications are *Autocad, cc:Mail, Draw, EDN, Interleaf, Mosaic, Novix, Office, Open Mail, Project, Quicken, RBase, Sun Mail, TEXN, TOMIS,* and *Word Perfect.*

1. Through the LAN and its *TIRS* file server, the suite gives local and remote PC's the ability to access CWD's *cc:Mail* system.

2. Through the LAN and its *CW1* file server, the suite gives some PC's[7] the ability to access *Draw, Novix, Office, Open Mail, Project, Quicken, RBase,* and *Word Perfect.*

3. Through the LAN and its *Unix* file servers, the suite gives *Unix* workstations, X-terminals, and some PC's the ability to access *Autocad, Interleaf, Mosaic, Open Mail, Sun Mail,* and *Word Perfect.*

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[7] CW1 is available to the senior staff, the Tomahawk divisions, and a limited number of users from the Systems Engineering and Logistics Directorates.

4. Through the LAN and one *Unix* workstation, the suite gives X-terminals the ability to access *EDN*.

5. Through terminal servers and a dial-up network, the suite gives PC's the ability to access *TEXN*.

6. Through an internal modem and a dial-up network, the suite gives one *Unix* workstation the ability to transfer *EDN* documents.

7. Through the *TIRS* file server and a dial-up network, the suite gives PC's the ability to access the Tomahawk community's *cc:Mail* system.

8. Through DISN/NAVNET-IP, the suite gives all user nodes the ability to access *TOMIS*.

## G. CONCLUSIONS

CWD regularly uses eight networks to help it perform its mission. This total includes a LAN, a backbone, three dial-up networks, and three WAN's. These networks work together to help the department interconnect entities and geographic locations, meet human needs, contend with political and cultural factors, maintain information flows, replace or supplement various exchange media, and support functional applications.

When examining the capabilities, one should remember that the networking suite does not exist in isolation. It is part of a larger system that includes such tools as the Automated Digital Network (AUTODIN), bulletin boards, the *JCALS* communications subsystem, and the telephone system. AUTODIN provides a means for passing classified and unclassified Naval messages. Bulletin boards help mobile employees exchange troubleshooting information. The *JCALS* communications subsystem is a prototype WAN that may provide a better means for exchanging technical manuals and other formatted documents. Finally, the telephone system supports voice, data, and fax communications. All of these tools provide some means for meeting the department's basic requirements.

# V. BASELINE EVALUATION

## A. INTRODUCTION

In the first phase of our project, we examined CWD's requirements. In the second, we examined the department's current capabilities. In this phase, we compared the requirements and capabilities. During the comparison process, we focused on the requirements that received inadequate support from the networking suite. By so doing, we were able to identify a set of key shortfalls.

## B. REQUIREMENT ONE VS. CAPABILITY ONE (ENTITIES)

CWD wants its networks to support the relationships that exist between itself and several internal and external entities. For the most part, the current suite meets this requirement. There are, however, three notable exceptions:

1. It does not support the production relationships that exist between CWD and surface combatants.
2. It does not support the production relationships that exist between CWD and regional maintenance organizations.
3. It does not support the production relationships that exist between CWD and many operational staffs.

## C. REQUIREMENT TWO VS. CAPABILITY TWO (GEOGRAPHY)

CWD wants its networks to provide the means to pass information to and from several geographic areas. For the most part, the current suite meets this requirement. There are, however, two notable exceptions:

1. It does not provide the means to pass information to and from Manama, Bahrain. This city is the permanent home of an operational staff and the temporary homeport of many surface combatants.

2. It does not provide the means to pass information to and from the Atlantic, Pacific, and Indian Oceans and their adjacent seas. Surface combatants regularly operate in these waters.

## D. REQUIREMENT THREE VS. CAPABILITY THREE (HUMAN NEEDS)

CWD wants its networks to meet the needs of people who interact with them. For the most part, the current suite fails to meet this requirement. Most significantly:

1. Some of its elements do not offer outstanding technical performance. Traffic on the backbone network is congested. Slow and unreliable communications lines are used to access remote applications and data. Large files must be transferred via tape. Finally, the *cc:Mail* network, which performs well today, does not have the capacity needed to meet all anticipated requirements.

2. It does not support efficient business processes. The document production process is a prime example. To produce documents, the department uses four word processing applications, two dial-up networks, and the postal system. With this complex web of physical information flows, CWD finds that it cannot perform effective version control, quality control, or workflow management.

3. It does not give technicians adequate time to devote to user support. The support staff is comprised of eight employees, many of whom have other jobs in the department. This small staff must manage a network that has few written policies, formal procedures, or management tools. It must maintain a network that has inconsistent back-up procedures, inadequate documentation, cluttered wiring closets, a large applications suite, and a complex web of

operating systems. Other departmental jobs, management tasks, and maintenance responsibilities occupy the attention of the staff. Its members do not, in general, have the time or energy to devote to end-user support.

4. It does not provide a simple means for passing information between remote sites. Before a user can access a particular organization or application, he or she must determine <u>how</u> to establish communications. This involves, among other things, choosing the correct access node, application, and network. For many people, this process is too complex and time-consuming.

5. It is not easy to maintain. Most of the LAN's wiring is not marked. The physical layout is not documented in sufficient detail. The wiring closets are unventilated and filled with broken computers. This situation adds to the support staff's burden and prevents users from receiving adequate support.

6. It is not easy to manage. CWD does not have the tools, policies, entities, or training programs needed to support effective management. The department has a copy of *Open View*, but it maintains this program on a slow, outdated computer system and uses it for nothing more than creating diagrams. There are no consistent policies for network management. For example, each file server's administrator follows his or her own "policies" for scheduling back-ups and storing tapes. The network does not have an operations center. Such a center, with the appropriate personnel and resources, could provide effective day-to-day management, coordinate troubleshooting efforts, and provide end-user support. Finally, the department does not have a comprehensive program for giving its technicians basic, intermediate, advanced, and repetitive training.

## E. REQUIREMENT FOUR VS. CAPABILITY FOUR (POLITICS/CULTURE)

CWD wants its network to provide a means for dealing with several political and cultural factors. The current suite satisfies some portions of this requirement while failing to satisfy others. Specifically:

1. It provides limited means for balancing development and maintenance requirements. The network provides access to high-capacity storage devices. In theory, this should give the department sufficient space to store the information associated with new <u>and</u> existing systems. In practice, most of the storage space is still dedicated to new systems [Ref. 21]. Therefore, the network continues to emphasize development to the detriment of maintenance.

2. It provides limited means for balancing sponsor and host requirements. The current suite is not ready to support the Defense Messaging System, Electronic Data Interchange, or C2-level security provisions of the Paperless Environment Project (PEP). This project is a priority item for the host. Until the network is ready to support PEP, observers will say that it emphasizes the sponsor's requirements to the detriment of the host's.

3. It provides limited means for achieving harmony with AIS Department. CWD needs a strong network management system before it can establish détente with its counterpart. The current suite has some tools, but it does not have the policies, procedures, and dedicated organizations needed to construct a strong management system.

4. Through *Windows for Workgroups*, it provides some means for maintaining the integrity of branch workgroups. Unfortunately, most branch workgroups do not have *Windows for Workgroups* or an equivalent system. As a result, they cannot benefit from the advantages of peer-to-peer networks.

5. It provides some means for supporting remote coordination between branch members. Remote users can gain dial-in access to *cc:Mail*. This capability

helps the distributed workgroups exchange simple messages and formatted documents. It does not, however, give them full access to the applications and data they need.

## F. REQUIREMENT FIVE VS. CAPABILITY FIVE (INFORMATION FLOW)

CWD wants its networks to support the flow of production, management, and coordination information. The current suite does not support this requirement adequately. Most significantly:

1. It does not give CWD a way to exchange product information with most of its customers. Products are normally delivered to customers through the postal system or AUTODIN. Feedback reports are normally sent to CWD (via type commanders and the Logistics Directorate) through the same channels.

2. It does not give CWD a simple, integrated way to exchange product information with its suppliers. The department must use one of the three dial-up networks to communicate with some suppliers. It can use the WAN's to communicate with others.

3. It does not give CWD a single, integrated means for exchanging management information with its seniors. Some management information is transmitted over the networks, but most of it is communicated through official correspondence, telephone calls, personal contacts, and message traffic.

## G. REQUIREMENT SIX VS CAPABILITY SIX (EXCHANGE MEDIA)

CWD wants its network to help it use, replace, or supplement simple messages, multi-version documents, engineering drawings, database records, letters, phone calls, and personal contacts. The current suite supports some portions of this requirement while failing to satisfy others. Most importantly:

1. It does not help CWD use Naval messages. These messages, whether classified or unclassified, are not supported by any of the networks. They are, instead, handled off-line through a stand-alone PC (running *Track Message*) and a series of manual processes [Ref. 9].

2. It does not help CWD replace Naval messages. The networks' E-mail systems do not provide a means for communicating with surface combatants and some land-based organizations. In addition, they do not provide a means for passing the classified or sensitive information contained in many Naval messages.

3. It does not help CWD use faxes. All faxes are received or transmitted through the telephone system and stand-alone fax machines. The department recently procured *Lotus Fax Server* but chose not to install it [Ref. 20].

4. It partially supports CWD's requirements for using multi-version documents. The networking suite helps the department exchange smaller documents with suppliers, and it allows the department to handle all documents in-house. It does not, however, give CWD a means for sending documents to most of its customers.

5. It partially supports CWD's requirements for using engineering drawings. Smaller drawings are produced by the network's *Autocad* and *Draw* applications and included in formatted documents. Larger drawings are handled by JEDMICS (a stand-alone system) and an aperture card library.

6. It partially supports CWD's requirements for using or replacing letters. The network provides the word processing applications used to generate some correspondence, and its E-mail systems give users the ability to exchange much of the information currently contained in letters. The network cannot, however, support the classified or sensitive information contained in many letters, and its applications do not support the processing of some formatted correspondence (*e.g.,* feedback reports and configuration change reports).

7. It partially supports CWD's requirements for replacing or supplementing phone calls. The E-mail systems give personnel another option for passing the information that is normally included in phone calls. Many customers do not have E-mail capabilities, and many situations require the interactive exchanges associated with phone conversations. Therefore, E-mail does not meet all of the department's needs in this area.

8. It does not support CWD's requirements for replacing or supplementing personal contacts. Employees are still required to travel extensively. Some meetings have been replaced by video teleconference (VTC) sessions. The VTC capability is not, however, supported by the network. It is provided, for a fee, by a local copier company that rents its VTC facilities [Ref. 1].

## H. REQUIREMENT SEVEN VS. CAPABILITY SEVEN (APPLICATIONS)

CWD wants its networks to support database management, document management, drawing management, messaging, presentation, project management, and resource management applications. The networking suite satisfies some portions of this requirement while failing to satisfy others. Most significantly:

1. It provides limited access to *Autocad, EDN, Interleaf, Open Mail,* and *Sun Mail.* These applications must be accessed by a *Unix* workstation, X-terminal, or PC running X-terminal emulation software.

2. It provides limited access to *cc:Mail*. This application cannot be accessed by the *Unix* workstations or X-terminals. The department recently procured *cc:Mail for Unix* but chose not to install it [Ref. 20].

3. It provides limited access to *Draw, Novix, Office, Project, Quicken,* and *RBase*. These applications are only available to the local PC's operated by the department's senior management, the Tomahawk divisions and branches, some Systems Engineering Departments, and some Logistics Departments.

4. It provides single-node access to *JCALS*. This application is accessed by a dedicated X-terminal. This terminal and its application are largely ignored by the user community [Ref. 18].

5. It does not support *JEDMICS*. This application is maintained in a dedicated minicomputer computer that is operated by the Logistics Directorate [Ref. 6].

6. It provides relatively poor access to *TEXN*. This remote application is accessed through a 9.6 kbps, dial-up line. Users complain that this connection is slow and unreliable [Ref. 4].

7. It provides relatively poor access to *TOMIS*. This remote application is accessed through a shared, 56 kbps, MILNET connection [Ref. 18]. Users complain that this connection is slow and subject to frequent failures [Ref. 4].

8. It does not support *Track Message*. This application handles classified Naval messages. Because the networks cannot carry classified data, this application resides on a stand-alone PC.

## I. CONCLUSIONS

In the baseline evaluation process, we highlighted the requirements that received inadequate support from the networking suite. These highlighted areas became our "key shortfalls." In the remainder of this section, we will summarize each of these shortfalls.

### 1. Shortfall One (Insufficient Reach)

*Reach* is "the extent of interconnection among people, location, and organizations [Ref. 11]." The networking suite does not have sufficient reach. It does not provide a way to communicate with many locations, including the major ocean areas. Furthermore, it does not support the relationships that exist between CWD and most customers.

### 2. Shortfall Two (Insufficient Range)

*Range* is related to "breadth of service [Ref. 11]." The networking suite does not have sufficient range. It does not give mobile employees access to all the applications and data they need. It fails to provide a way for customers to receive product information or submit feedback. It transports only a small portion of the management information that CWD exchanges with seniors and subordinates. It cannot handle Naval messages, faxes, phone calls, or VTC sessions. It inadequately supports the transfer of documents, drawings, and letters. It fails to give *Unix* workstations the ability to use *cc:Mail* or Harpoon divisions the ability to use most *Windows* applications. Finally, the suite provides no access to *JEDMICS* and *Track Message*, single-node access to *JCALS*, and poor (*i.e.,* slow and unreliable) access to *TEXN* and *TOMIS.*

### 3. Shortfall Three (Insufficient Responsiveness)

*Responsiveness* is "the quality and reliability of network service [Ref. 11]." The networking suite does not have sufficient responsiveness. The backbone is slow, congested, and prone to failure. Some TCP/IP connections and dial-up lines are slow and unreliable. The *cc:Mail* dial-up system is relatively fast, but it does not have the capacity to meet the anticipated growth in demand.

### 4. Shortfall Four (Insufficient User Support)

Users need training and documentation to guide them through their work processes. In addition, they need troubleshooting support to help them overcome problems. Unfortunately, these needs are not addressed adequately. Technicians, driven by other requirements, have little time to devote to user support.

### 5. Shortfall Four (Insufficient Workgroup Support)

Most branch workgroups do not have access to a peer-to-peer network operating system (*e.g., Windows for Workgroups*). Such a system could help employees share files and printers while continuing to enjoy access to the network's file servers, terminal servers, printers, and other facilities.

### 6. Shortfall Six (Too Much Complexity)

The networking suite includes three kinds of cabling, three types of user node, four operating systems, two network operating systems, a LAN, a backbone, three WAN's, and three dial-up networks. Furthermore, it supports seventeen applications. This arrangement is too complex. It increases the workload for the users and technicians. It inflates the operations and maintenance costs, and it makes it harder for the department to improve such basic processes as document production.

### 7. Shortfall Seven (Insufficient Maintenance and Management)

CWD does not have the tools, documentation, policies, entities, or training programs needed to maintain or manage its networking suite effectively. The only tool in regular use is a protocol sniffer. The physical layout is not documented in sufficient detail. There are no consistent policies for network maintenance or management The department does not have a dedicated support staff or a network operations center. Finally, CWD does not have a comprehensive plan for training, educating, and developing its technical support personnel.

# VI. TARGET ENVIRONMENT

## A. INTRODUCTION

In this chapter, we research answers to the fourth research question, regarding anticipated future requirements for CWD's computer network. The problem associated with trying to determine the optimal networking structure for an organization's future is knowing what that future holds. To compound this problem, a functioning network does not adapt to changes overnight. This means that the organization must plan network changes and invest its resources in advance of when its optimal network is needed. In short, there is a certain amount of risk involved in any change made to an organization's computer network structure. We propose that an organization can reduce the amount of risk by developing a clear vision of where it wants to go, planning the network appropriately to support that vision, and examining networking trends in industry to better understand what concepts have a high probability of affecting future networks.

We cannot overstate, however, that the computer networking industry is one where rapid and unpredictable changes are common. Typically there is no one "right answer" to every organization's needs. What works in one organization may not work in a similar organization. Our goal is to provide some insight into the requirements of CWD's target computer network. We conclude with a comparison of the examined trends to the current network requirements as presented in Chapter 3, Baseline Environment. From this we establish our anticipated requirements for CWD's target network in the year 2000.

## B. THE FUTURE WORK ORGANIZATION

The work environment is already changing from our traditional image. Perhaps the most striking difference is that the typical hierarchical structure of organizations is quickly fading. [Ref. 27] This structure is not equipped to deal with rapid change

because of the ways in which information, instructions, and other interactions must travel up and down the "chain of command" in order to coordinate with the various parts of an organization. Fast paced changes in the business environment require that organizations be able to communicate and coordinate across all facets of the organization. The tightly structured lines of departments and divisions will begin to fade and more emphasis will be placed on dispersed decision making.

An indicator of the move toward more horizontally structured organizations is the trend in work groups. More and more, organizations are relying on task oriented teams as the major working unit to accomplish major tasks. [Ref. 27] This involves taking individuals who may be from different divisions and combining them into one team for the life of a particular project.

The project team concept brings up many communication related issues for the members of the team. Each of the team members may have different reporting responsibilities. On one hand a member reports to the team leader or designated supervisor, but on the other hand that same member reports to his or her traditional division supervisor. A viable network must be able to handle the change in typical communication patters which before had been primarily within one's own division. "Groupware" products are one tool to assist this team project concept.

Today's workers are becoming more mobile than ever before. This is, in part, due to the improvements in communications and computing power. Such improvements give workers the flexibility to move away from their traditional office, but retain the capabilities that they had from their desktop computer or other office support materials. [Ref. 27] This concept can have a major effect on designing the appropriate network structure for the organization. It will have an effect on local LAN segments as well as WAN connectivity if worker mobility requires them to move greater distances. An architecture must be able to support workers with the growing demands accompanying mobility requirements.

A final issue for the work organization of the future is that there will be a renewed focus on key business processes of the organization caused by the customer's

demand for quality. [Ref. 27] The primary driving factor behind this trend is competition in markets. Even though DoD is not driven by market competition or profit, it will be focusing on quality issues as well. Information systems will be key in assisting the organization of the future that desires to improve organizational performance by examining its business processes.

## C. THE FUTURE INFORMATION ENVIRONMENT

The biggest change in the information environment is already occurring. Data itself is changing. Instead of the traditional textual forms of data, it is assuming more dynamic forms, such as images, voice, video, and combinations of many of these. [Ref. 28] A network designed to support textual forms of data is fairly simple. Supporting these new forms, however, is much more complex, requiring faster processors, better storage mechanisms, and greater bandwidth support just to name a few required network improvements.

Organizations are allowing greater access to corporate databases. Individuals require access to more data and information so that they can do their jobs based on better information. [Ref. 28] This democratic access to enterprise data results in a much higher workload for the organization's networks. Accompanying this shift in dissemination of corporate data is a shift from host-based computing to client/server computing [Ref. 28] as well as distributing data throughout the segments of an enterprise network. [Ref. 27]

The concept of distributing data, along with open system interconnection and cooperative processing will lead to the development of *distributed systems*. [Ref. 27] Open system interconnection refers to standardizing interfaces that allow products to interoperate across multivendor networks. Using standard interfaces allows a large organization with many individual LAN segments to connect these segments over a backbone to form an organizational internet. These types of systems will give organizations the flexibility to choose whatever products and designs best serve

individual segments, the ability to internetwork these various differing segments, and the usefulness of extending current IT investments by building on already existing networks.

## D. THE FUTURE APPLICATIONS ENVIRONMENT

The increasing capabilities of desktop computing are changing the structure and use of applications in the office environment. Desktop computers have faster processors, better peripherals, and are supported by more reliable transmission media. They are now able to perform operations that were formerly reserved for the higher end computing environment of mainframes. [Ref. 27] This allows users to run applications from their desktop computers that were once able to run only on the high end platforms. Programs such as CAD/CAM and videoconferencing will be more common in the future.

Supporting high-end applications to the desktop has several implications for the computer network that supports such applications. First, the traffic on LAN segments will increase as these high end applications become more available. [Ref. 29] Traffic will be shifting from dedicated data lines to local area networks. [Ref. 28] Greater bandwidth and faster speeds will be required to effectively support these applications. Finally, networks will require the flexibility of supporting differing bandwidth requirements. [Ref. 28]

Applications will also be using more graphical user interfaces, GUIs, because they provide a more simple working environment for the user. GUIs, however, increase the size of files and thus have some of the same effects on networks as other high end applications. [Ref. 29]

The trend towards interactive multimedia is one of the largest to effect applications and the networks which support them. Definitions of multimedia vary, but this one is presented to encompass the fullest sense of multimedia as a tool that offers [Ref. 28]:

1. Multiple delivery mechanisms (CD-ROMs, LANs, WANs)
2. Multiple types of content (video, audio, graphics, and text)
3. Multiple applications (videoconferencing, video or audio electronic mail, etc.)
4. Multiple delivery locations (offices, homes, cars, and client sites).

Traditional LANs, such as Ethernet and token ring, rely on shared bandwidth. The use of dynamic data in multimedia requires networks that can provide continuous, uninterrupted data transfer in a predictable manner. This type of data is called "isochronous" because it requires equal time intervals between packets or cells of data. Therefore, supporting interactive multimedia will require real-time systems with a flexible means of supporting *dedicated* bandwidth requirements. [Ref. 28]

The trend towards project teams as the work unit within organizations will lead to groupware applications. These are computer applications that are designed to support communication and interactions among people as they work in groups. [Ref. 27] These products vary according to the support the organization requires, but common tools provided by a groupware product include [Ref. 27]:

1. Idea Generation (Brainstorming, topic commenter, group outliner)
2. Idea Organization (Issue analyzer, group writer, vote selection, questionnaire)
3. Policy Development (Policy formation, stakeholder ID)
4. Session Planning (Session manager)
5. Organizational Memory (Enterprise analyzer, graphical browser, group dictionary).

Another characteristic of groupware products is that they support differing time and place requirements of the individuals in the group. In other words, not all group members have to be in the same place at the same time in order to interact with the group's ideas and work in progress. [Ref. 27]

These types of products require a capable network for support. For example, the network must be able to support frequent and varied types of email, connectivity to local and remote LAN segments (i.e. WAN connectivity), and interoperability among possibly differing systems.

## E. THE FUTURE NETWORKING ENVIRONMENT

### 1. Broadband Technologies

An important shift in the networking environment is the move to broadband technologies. Broadband telecommunications refers to more than one signal traveling over a communication medium at one time. This move to broadband technology support is accelerated by things like the improvements in computer hardware (better processors and peripherals), multimedia computing, and the move to distributed systems.

Three trends are creating a need for broadband technologies. [Ref. 30] First, there is an increased traffic load on local LAN segments. This occurs because more and more users are requiring access to the organization's networks. There are many reasons for greater user access requirements, but basically, workers cannot efficiently do their jobs without access to computers. An ever increasing amount of work is conducted by fax or email. Some of this work would have previously been handled by a telephone call or a letter, but today people prefer the ease of electronic communications. [Ref. 27]

The shift to client/server computing is also increasing the traffic load on local LAN segments. Organizations can reduce their software costs and administer copyright obligations easier by installing application programs on the server. As users need access to the program, the server electronically transfers that program to the desktop, thus resulting in greater LAN traffic than if the program were stored at the desktop. [Ref. 29] It is also important to note that when using Windows applications on a client/server network many support files must be installed and maintained on the client.

The second need for development of broadband technology is that current applications are stretching LANs to their limits. Desktop applications, such as computer aided design (CAD), computer aided manufacturing (CAM), and large database files have large bandwidth requirements. Time-sensitive applications, such as video and multimedia, require both high bandwidth and low end-to-end delay. As broadband technology matures, the popularity of these types of applications will grow, thus creating a requirement for the LAN to be able to support them.

The final need for broadband technology support is the increased internetworking between local and remote LAN segments. What were once "islands" of LAN segments among an organization are being connected via a network backbone to create an internet or enterprise network. [Ref. 27] This provides many advantages to the organization as a whole. A organizational internet allows all facets of the organization to communicate. It provides a means for different segments to build on the technology and design characteristics that best suit their individual needs. It also allows the organization to build on the investments it has already made to the networks without having to reconstruct common networks from scratch.

### 2. Internetworking

The move to creating enterprise networks is a result of various changes in technology and the telecommunications industry. First, the reach of networks is expanding organizationally. Not only can single-organization networks span a much greater geographical area, but networks that incorporate the different organizations within one industry are beginning to emerge. For example, J.C. Penney's network ties in its employees as well as the manufacturers of apparel and fabric. J.C. Penney can electronically order fabric and material which is automatically delivered to the apparel manufacturers. [Ref. 27] This process allows all involved to operate in a just-in-time (JIT) fashion. This reduces overhead costs to the organizations involved.

Also, the communications industry is being destabilized. Organizations do not rely on local telephone companies for providing access to telephone services as they once did. Additionally, the restrictions on the Regional Bell Operating Companies (RBOCs) will be coming to an end. Restrictions currently prevent RBOCs from selling information services, manufacturing telecommunications equipment, and providing long-distance services. [Ref. 27] Lifting some of these restrictions will allow for a more competitive marketplace for telecommunications support and will erase the distinctions between local and long-distance telecommunications businesses. [Ref. 27]

Global network services are emerging. Deregulation of the communications industry is occurring worldwide and companies within the industry are forming alliances to provide global networking services. [Ref. 27] This is important for organizations that prefer to use vendor managed international data networks rather than incur the additional problems associated with building and operating their own private international networks.

New technologies are improving bandwidth use. LAN technologies are increasingly allowing greater bandwidth to the desktop and data compression technologies are allowing users to pass more data. [Ref. 27] Both of these technologies result in more affordable networks.

Finally, electronic mail may provide a new communication infrastructure. Many believe that email will become the infrastructure for information distribution in the future. This is spawning a new generation of applications (mail enabled applications) designed for distributed systems that rely on email as the communication platform. [Ref. 27]

### 3. Changes in the Telephone Industry

The role of telecommunication networks within the telecommunication industry is currently undergoing drastic changes. The traditional telecommunication networks have supported high quality voice between telephones. Now, telecommunication

networks are increasingly being used to transmit data rather than voice. [Ref. 31] This trend is causing a major paradigm shift for communication providers, because there is a relatively large increase in the demand for data services (20-33% annual growth) as compared to the demand for traditional voice services (2-5% annual growth). [Ref. 32] Telephone companies are adapting to meet these changes so they are not forced out of the market by changing demands.

Two primary developments are leading the shift for telecommunications companies. First, telephone networks are becoming more computerized. This is a result of the shift from analog to digital telephone technologies and the increase in service offerings, such as call waiting and call forwarding. Second, the introduction of high capacity fiber is allowing telecommunications companies to consolidate transmission lines. Fiber allows these companies to replace hundreds of copper wires with one fiber optic line. It is more reliable and easier to maintain, and it has better error properties than copper. One additional characteristic of fiber is that it provides much greater bandwidth capacity than voice networks will ever likely need. [Ref. 31] This places the traditional "telephone companies" in a good position to offer data networking services, and makes them a huge competitor to the traditional computer companies also vying for a position in the computer networking market.

#### 4. Mobile and Wireless Computing

The issues of the mobility of workers and the advent of wireless computing technologies are analogous to the chicken and the egg, "Which came first?" The simple answer is that it does not really matter. The growing desire for workers to become more mobile is pushing the development of wireless computing technologies. At the same time, as these technologies increase, they allow workers to become even more mobile. This coming generation of mobile computers will be designed specifically for those out of the office workers. It will emphasize facsimile and speech media that are particularly useful to mobile workers. [Ref. 33]

The future of mobile computing will allow an individual to access any information, at any time, from any place using a new form of computer known as the pericomputer. "As computers become mobile, wireless connections will proliferate until the information network becomes virtually ubiquitous." [Ref. 33] This new form of computing will have a domino effect on other aspects of networking.

Software will have the greatest change in the new, mobile computing paradigm. It will be written with an eye to the group as well as to the individual. Groupware products will proliferate and, indeed, become more worthwhile when wireless communications allows users to gain access to it at will. [Ref. 33] Software distribution will also become simpler. Users will be able to download software electronically in a matter of minutes. Software vendors will package software into smaller units in order to transmit it more easily. Applications will also be easier to customize based on selectable features. Instead of having to purchase an upgrade to a particular version of an application, a user will be able to select and pay for only the features he or she desires. [Ref. 33]

Before moving to mobile networked computing, there are improvements that must be made to support such a technology. [Ref. 33] Compact, power-thrifty video screens are an absolute necessity for pericomputers. The cost and consumption of electric power is another major concern which can be addressed by developing components that require less power or developing better batteries. Technologies of handwriting and speech-recognition must be developed because they make mobile computers easier to use. The transmission medium will also pose a potential limitation to mobile computing. Some of the problems inherent in cellular telephone networks will apply to mobile computing as well. Software must be developed so that people can easily resume interrupted communication. Finally, the human aspects of mobile computer networking must be addressed. This type of connectivity raises particular concerns in the areas of security and personal and business privacy. [Ref. 33]

## F. CONCLUSIONS

The next logical question to ask is, How will these changes effect the design of CWD's optimal computer network? First, we need to review the requirements of CWD's computer network as presented in Chapter III, Baseline Environment. Those requirements are:

A. Support production, management, and coordination relationships among internal and external entities.
B. Support entities from various geographic areas.
C. Support the needs of diverse groups of people.
D. Balance the politics and culture of the organization.
E. Support a simplified flow of production information.
F. Support a simplified flow of management information.
G. Support a simplified flow of coordination information.
H. Support a simple exchange of media.
I. Support a diverse set of applications requirements.
J. Support various applications through a simplified network architecture.

Next we need to review the organizational, information, applications, and networking trends presented in this chapter. They include:

1. Fading hierarchical structure.
2. Task oriented teams as the basic "work unit."
3. Greater mobility of workers.
4. Focus on key business processes of the organization.
5. Dynamic data.
6. Greater access to corporate databases.
7. Distributed data.

8. High-end applications to the desktop.
9. GUI use for applications.
10. Interactive multimedia.
11. Groupware applications.
12. Broadband technologies.
13. Internetworking.
14. Changing telephone industry.
15. Mobile and wireless computing.

Table 2. Requirements versus Trends combines these two factors to show which trends are likely to effect the requirements of CWD's network. Notice that each requirement is effected by at least one trend, and each trend effects at least one requirement.

**REQUIREMENTS**

| TRENDS | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ■ | | | ■ | | ■ | | | | |
| 2 | ■ | ■ | ■ | ■ | | ■ | ■ | | | |
| 3 | ■ | ■ | ■ | ■ | | ■ | | | | |
| 4 | | | ■ | | | ■ | | | | |
| 5 | | | | | ■ | | ■ | ■ | ■ | |
| 6 | | | | | ■ | | | | ■ | |
| 7 | | ■ | | | ■ | | | ■ | ■ | |
| 8 | | | ■ | | ■ | | ■ | ■ | ■ | |
| 9 | | | ■ | | ■ | | ■ | ■ | ■ | |
| 10 | | | ■ | ■ | ■ | | ■ | ■ | ■ | |
| 11 | | | | ■ | ■ | ■ | ■ | | ■ | |
| 12 | | | ■ | | ■ | | | | | ■ |
| 13 | | | ■ | | | ■ | | | | ■ |
| 14 | | | | | | ■ | | | | ■ |
| 15 | | ■ | ■ | ■ | | ■ | | | | ■ |

**Table 2. Requirements vs. Trends**

The implications of these changes are that CWD's future network will have the following requirements:

1. Provides access to a greater number of users from various locations.
2. Enables flexible access to data and applications based on project requirements, while at the same time provides security to those not requiring access to specific project information.
3. Allows changes to the computer network as business processes direct.
4. Encourages mobility of workers.
5. Supports an ever increasing variety of data forms.
6. Provides for the distribution of data to different resources.
7. Supports use of high-end applications typical of engineering requirements (i.e. CAD/CAM, graphic and drawing programs, publishing applications)
8. Supports multimedia and groupware applications.

These types of characteristics are best supported by the trends in networking technologies to move to broadband technologies and support internetworking within the organization. There are many options and choices to be made for organizations moving in this direction. Chapter VII, Target Evaluation will examine many of the capabilities that will be available in the year 2000 to support the requirements discussed here.

# VII. TARGET EVALUATION

## A. INTRODUCTION

Chapter VI, Target Environment, concluded with a summation of the requirements for a CWD future network. Now we must examine the capabilities likely to be available to CWD in the year 2000 to support these requirements. In accomplishing this we examine some of the necessary components for a computer network.

Simply defining the components required for a network is often a difficult task. While many things are important to the effective operation of a computer network, we had to limit the scope of these items to a manageable level. We have focused our research mainly on the internal changes that CWD can make to improve its network, specifically choosing a network technology to support future requirements. We also included an examination of the following: broadband technology, network operating systems, transmission media, and management tools.

## B. LAN TECHNOLOGY

There are many factors that are currently or will be taxing the capabilities of CWD's networks. These factors include:

1. the increasing number of packets being sent on CWD's networks,
2. the increasing size of these packets,
3. the increasing number of users on the network,
4. the demand for high-end applications to the desktop,
5. the advent of multimedia applications,
6. the mobility requirements of workers.

It is easy to see that current Ethernet and Token ring networks operating at 10 and 16Mbps will not be sufficient to support CWD's future network requirements. With this plus CWD's desire to learn more about 100Mbps transmission options in mind, we examined three variants of Ethernet, FDDI, and ATM.

There were differing reasons for selecting each. Additionally, our general perception during initial research was that these are three industry leading technologies for 100+ Mbps transmission rates. We examined the Ethernet variants 100BaseT, 100VG-AnyLAN, and Switched Ethernet, because CWD's current use of Ethernet would make it an easy upgrade. [Ref. 17] We examined FDDI because it is one of the more well established, faster transmission rate technologies plus NSWC PHD has plans to migrate to an FDDI based campus backbone. [Ref. 34] Finally, we chose ATM because our initial research indicated that it has tremendous potential as both a LAN and WAN technology. The following three sections are discussed in greater detail in Appendices D through F.

### 1. Ethernet

Ethernet is a relatively inexpensive and popular LAN technology. Three options for installing or upgrading a "faster" Ethernet are discussed in Appendix D, Ethernet. These options are "Fast Ethernet" (100BaseT), 100VG-AnyLAN, and Switched Ethernet. Because CWD already maintains a 10BaseT Ethernet network with Category 3 UTP, these three options provide alternatives for upgrading to a higher capacity network. [Ref. 18] It is important to understand, however, that Ethernet based on UTP does not protect against noise and it is not a secure medium. Any organization seriously considering upgrading its network must also consider installing cable that will better support these concerns, for example, multimode fiber optic cable.

An organization desiring to upgrade to one of those forms of Ethernet will make that decision based on their particular circumstances and networking needs. For an organization that already maintains a 10BaseT LAN and is looking to strictly limit

upgrade costs, 100BaseT may provide a good option. Providing that the network nodes are not geographically disperse and that the network is correctly wired (minimum of four pair Category 3 UTP), 100BaseT may be sufficient. 100VG provides a good upgrade path for an organization desiring to create an enterprise network from both Ethernet and token ring LAN segments. Finally, Switched Ethernet provides a more flexible means of upgrading existing traditional Ethernet LANs. If not all users require high-speed transmission, Switched Ethernet can support both the traditional and faster transmission rates. It also provides an incremental upgrade path in which segments of the LAN can be upgraded separately. This allows the organization to spread upgrade costs over time rather than absorbing the costs at once.

### 2. FDDI

The specific characteristics, advantages, and disadvantages of FDDI are discussed in Appendix E, FDDI. FDDI is capable of supporting many of CWD's network requirements. It provides a high bandwidth to support the high-end applications associated with CWD's engineering functions. It provides high network availability to support critical functions. It provides throughput guarantee for such transfers as those involved in document creation, review, and publishing. Finally, it provides high security to protect the sensitive nature of the information being processed.

FDDI is capable of providing excellent support for all of those requirements. [Ref. 35] It does so, however, at a considerable cost. This cost comes not only in purchasing the appropriate hardware to support FDDI connections, but the largest part of expenses would be for recabling. CWD currently has 50 micron multimode fiber connecting its smart hubs and servers and NSWC PHD has 50 micron fiber supporting the campus backbone. [Ref. 17, 19] FDDI typically runs on 62.5 micron multimode fiber, although Category 5 UTP or single mode fiber are also supported. It is possible to support 50 micron fiber, depending upon the power budget for the cable, but only 62.5

micron fiber is the official multimode cable standard. [Ref. 36] Regardless, CWD would be required to recable a major portion of its network transmission media.

There are planned upgrades to install FDDI as the campus backbone under the Paperless Office Project. [Ref. 34] It would be possible to install CWD's LAN as a hub connected to this backbone.

### 3. ATM

The issues surrounding the need, development, functioning, advantages, and disadvantages of ATM are discussed in Appendix F, ATM. In theory, ATM will provide the greatest amount of flexibility to an organization. It is found mostly in WANs today, but is capable of providing support to the desktop. The simplicity involved in relying on one technology for all of your networking needs is one of the biggest advantages of ATM. In addition to its wide "reach," ATM provides effective support for more types of data than any other technology. The small cell size and the switched architecture make ATM viable for all types of data, such as, voice or video requiring circuit-switched type service and text which is better suited by packet-switched type service.

The factors preventing many organizations from entering the ATM world are its high cost and its developing standardization.[1] The "newness" of ATM is responsible for both of these factors. While such powerful capabilities will always come at a price, the cost of ATM is likely to drop once it has been on the market for a while. Time will also allow the standards to mature and make ATM a less risky technology move.

CWD may not want to make a jump to ATM right away. Should other DoD resources migrate to ATM support, however, CWD may want to consider this option. Migrating to a full ATM network can be accomplished in an incremental process. CWD is already planning to upgrade its network. NSWC PHD is already planning to upgrade its campus backbone to FDDI. These two upgrades may be sufficient to support CWD's needs for years to come. If, however, a desire to migrate to ATM becomes a

[1] For example, the cost of an ATM switch ranges from $5,000 - $12,000 and an ATM network adapter from $1,000 - $4,000. [Ref. 55]

requirement, it can be accomplished fairly easily. The migration process would involve moving to an ATM supported WAN, then an ATM supported campus backbone, and finally an ATM supported CWD LAN. The costs and risks involved in these three steps could be spread out over an extended period of time based on the organization's goals and time frame.

## C. BROADBAND TECHNOLOGY

Chapter VI, Target Environment discussed the issues behind the push for broadband technologies. To review, three basic reasons behind the need for high-bandwidth technologies are the increased load on local LAN segments, internetworking between local and remote LAN segments, and the increasing use of high-bandwidth desktop applications. [Ref. 30] Broadband technologies are what will form the backbone of enterprise networks. In the past, and still continuing today, organizations have used various different options, such as modems and dial-up phone lines, point-to-point leased lines, T1 lines, switched digital facilities and ISDN, or X.25 services to provide the advanced communication requirements for their growing networks. In the future, as networks expand and internetworking becomes more pervasive, installing a sufficient number of these types of circuits is likely to become economically prohibitive. To meet the growing network bandwidth requirements, three technologies offer a more cost effective solution to the options listed above. These include frame relay, Switched Multimegabit Data Service (SMDS), and ATM.

CWD currently has WAN access to three resources: a T1 connection to NEWNET, a fractional T1 connection to NAVNET, and a 56 kbps connection to DISN. [Ref. 18] Because these three WANs are not under CWD's control, decisions regarding broadband technology support are out of its authority.

CWD needs to make a strategic decision regarding its external connectivity. The choices include retaining the current external resources, establishing and financing its own external connectivity, or a combination of the two. By keeping the current system,

CWD will not incur additional costs and as these DoD WANs upgrade their services in time, CWD will have better service without incurring the upgrade costs either. Until such upgrades occur, CWD would have to accept the current services. By establishing its own external connectivity, CWD gains control of these resources, but also incurs the associated costs. Whatever the decision, it is important for CWD to understand how these technologies will support such WANs in the future in order to make better informed decisions about the networking issues that are under its control.

#### 1. Frame Relay

Frame relay is a connection-oriented service where frames of data are transported across public circuits using statistical multiplexing. [Ref. 37] It is a public transport network that is positioned to replace individual leased lines for WAN communications. This is particularly beneficial for organizations with a mesh type topology, because the cost of maintaining multiple point-to-point leased lines can quickly become cost prohibitive.

Frame relay is actually an interface specification whose protocol operates at the Data Link layer only, and does not include any Network or higher layer protocol functions. [Ref. 38] This reduction in the protocol overhead is possible because of two things. First, frame relay relies on the underlying Physical Layer transport to be relatively error-free (i.e. "clean" lines) and second, that the higher layer protocols of the endpoint devices will be responsible for all error recovery functions. [Ref. 38] Reducing the protocol processing done by the network also reduces the transmission latency. [Ref. 37]

This interface specification defines the standards for transfer of frames at the user-network interface (UNI), which is the demarcation point between the terminal equipment, maintained by the end user, and the transport facility, maintained by the service provider. As the network accepts the frames of data it reads the address information, multiplexes the frames, and routes each to its destination over a virtual circuit. Each frame contains a Data Link Connection Identifier that identifies it with a

particular "conversation." This allows each physical frame relay interface to contain many individual conversations. [Ref. 37]

Frame relay standards support two types of virtual circuits. Permanent virtual circuits are established when the endpoints of the communication path are the same every time. They are very similar to a dedicated leased line, however the actual path of the data may be different every time. Switched virtual circuits are similar to the telephone system where a user may connect with someone different every time. [Ref. 37]

Some of the benefits of frame relay include reduced internetworking costs, increased performance with reduced network complexity, and increased interoperability via international standards. [Ref. 37] Frame relay is also anticipated to be used with ATM in the future. Because the actual transport mechanism is separate from the frame relay interface specification, ATM could provide an excellent network infrastructure for transporting frame relay data. [Ref. 37]

Frame relay service is available at rates up to DS1 from most of the regional Bell operating companies. This list includes Ameritech, Bell Atlantic, BellSouth, NYNEX, Pacific Bell, Southwestern Bell, and US West. Interexchange carrier service is provided by AT&T, CompuServe, MCI, Sprint, and WilTel. [Ref. 38]

### 2. SMDS

SMDS is a broadband technology developed by Bellcore and is a subset of the IEEE 802.6 Distributed Queue Dual Bus metropolitan area networking technology. It was designed to be a connectionless, high-speed, public, packet-switching service providing an extension to users' LANs across greater distances. The benefit behind connectionless service is that no time is spent in establishing a path for the data, which simply travels over whatever route is available at that time. [Ref. 30] Because it is a metropolitan area network specification, SMDS has been primarily limited to use within LATAs, but the Interexchange carrier MCI is beginning to offer wide area transport. [Ref. 39]

SMDS offers speeds from 56 Kbps to 34 Mbps and data transfer to anyone who subscribes to the public packet-switched data network. [Ref. 39] It can also limit transmissions within a closed user group by using special features such as call screening and verification and blocking, thus creating a virtual private network. [Ref. 40]

SMDS defines a three-tiered architecture with a switching infrastructure comprised of SMDS-compatible switches, a delivery system made up of T1 and T3 circuits called Subscriber Network Interfaces (SNIs), and an access control system for users to connect to the switching infrastructure without having to become part of it. The demarcation point between the customer premises equipment (CPE) and the network occurs at the SNI. From that point, the CPE connects to the SMDS carrier switch via DS0, DS1, or DS3 physical connections.

Some of the key features offered by SMDS include: high-speed, low-delay connectionless data transport, any-to-any connectivity, multicasting, CCITT E.164 addressing, support for key protocols used in local and wide area networking, network scalability, SNMP-based network management, and security features with call blocking and validation and screening. It is currently offered by Ameritech, Bell Atlantic, BellSouth, GTE, Pacific Bell, US West, and MCI. Flat rate tariffs for service typically ranges from $350 to $750 per month, plus a one-time installation fee per subscriber network interface of $700 to $1,000. [Ref. 40]

### 3. ATM

Earlier, and in Appendix F, we discussed the characteristics and benefits of ATM. This discussion was primarily from the viewpoint of ATM as a LAN technology. It is important to understand that one of the unique characteristics of ATM is that it is also an effective broadband technology. The fixed, small cell size and the switched architecture of ATM allow it to function efficiently on both of these levels. Also, being able to use one technology for any scale network has the added advantage of simplicity.

## D. NETWORK OPERATING SYSTEMS

Demands for improvement in three areas have forced the challenge to expand network operating system (NOS) capabilities. First, hardware platforms and peripherals have advanced to the point where 32-bit computing and hundreds to thousands of megabytes of storage capacity are commonplace. Second, support for standard internetworking protocols is being added to the core systems of most NOSs. Finally, the move towards internetworking requires *interoperability*. [Ref. 41]

Historically, Novell has dominated the NOS market. [Ref. 42] Today other developers are challenging Novell's reign in the NOS market, and are becoming just as capable at supporting improved NOSs.

Until recently, Novell's NetWare 3.12 has been the "king" of NOSs throughout the industry. Other giants in the industry, such as IBM, Microsoft, and Banyan Vines are attempting to pull some of that market share away from Novell. [Ref. 43] The most obvious demonstration of that market share "competition" is that those three NOS producers, as well as Novell, itself, have made a considerable effort to ensure they have a migration path from NetWare 3.x to their newest releases. [Ref. 44]

The four biggest contenders for the NOS market of the future include: Novell's NetWare 4.1, Microsoft Windows NT 3.51, IBM's LAN Server 4.0, and Banyan Vines 5.54. Each of these products offer a high-performance, 32-bit, PC-based server operating system, file and print services, and some kind of multiserver directory services for simplifying the management and administration of multiple servers. [Ref. 44] We will look at the key features of each of these that might assist an organization in selecting the appropriate NOS.

### 1. Novell NetWare 4.1

The biggest advantage for Novell is that it has held the largest share of the NOS market for a long time. Not only has Novell accumulated many pleased clients, but it

also has a rich infrastructure of partners, resellers, education and certified professionals. [Ref. 45] It has the largest presence of third-party applications and tools of any of the NOS producers, and no other producer has the extensive educational programs as does Novell.

That is not to say that NetWare 4.1 must rely on Novell's past reputation, because the product is considered by many to be the best on the market. NetWare 4.1 was reviewed along with Windows NT 3.5, LAN server 4.0, and Banyan Vines 5.54 in the May 30, 1995 issue of *PC Magazine* and was rated "Editors' Choice," for its integrated management utility, improved management facilities, improved installation, and the unique power of its NetWare Directory Services (NDS) global distributed database. [Ref. 44]

Most authors agree that NDS is what sets NetWare 4.1 above the other competitors. The main function of NDS is to regulate access to network information, resources, and services. [Ref. 46] It accomplishes this through a relational database distributed across the entire network. Users are able to log in to a multiserver network and view the entire network as a single information system where they have access to all network resources regardless of their location. [Ref. 41]

This very powerful tool makes NetWare 4.1 particularly suited for enterprise networks. NDS provides a global naming service where you can assign meaningful and unique names to network objects. It provides a structured approach to security and to network management, and it has the advantage of location independence. [Ref. 46] The only other product to provide a global naming service somewhat similar to NDS is Banyan Vines 5.54 with its StreetTalk III. It does not, however, provide the same overall capabilities as NetWare 4.1.

### 2. Windows NT 3.51

The gaining popularity of Windows NT is one of the more significant changes in the NOS market. Microsoft is clearly trying to find a place in the NOS market, and is

willing to provide the easiest upgrade for NetWare 3.x users to accomplish this. [Ref. 47]

Traditional file and print services no longer differentiate a NOS product as they may have once done. Today, application services, meaning database, messaging, or communications programs running on the server that interact with related programs on the clients in a distributed fashion, are one aspect that is beginning to set NOSs apart. [Ref. 44] Windows NT, because of its 32-bit, preemptive multitasking, multithreading environments, memory protection, and multiprocessor capabilities, is considered a leader in application services. [Ref. 44]

Microsoft's strategy for Windows NT is to sell both an operating system and the applications. The application suite, called Microsoft BackOffice, contains Microsoft Systems Management Server for node and application management, Microsoft SNA Server to connect to IBM hosts on an SNA network, Microsoft SQL Server, a client/server database, and Microsoft Exchange, a mail server. [Ref. 47]

*PC Magazine* considered Windows NT to have the best NetWare migration and integration tools of the four products mentioned earlier in its review. Also, its hardware auto-detection and intuitive configuration steps make it an excellent product for initial network installation. [Ref. 47]

Windows NT does not have a global directory service as does NetWare 4.1. Instead, it uses domain directory services. This type of directory service allows network managers to group users and resources together logically into a domain controlled by a server called a primary domain controller (PDC). Microsoft has improved on its domain model by adding a service called Interdomain Trust (IT). Under IT, the PDC in your home domain communicates with PDCs in other domains and vouches for you and your requests, thus simplifying the process of accessing network resources. [Ref. 44]

Finally, another popular feature of Windows NT is its pricing scheme. The server license for Windows NT 3.5 costs $699 with an additional $39.95 for each client

license.[2] [Ref. 43] In many cases this is more cost-effective than paying for multiple client licenses that are not used because the organization does not need that many licenses.

### 3. IBM LAN Server 4.0

IBM LAN Server 4.0 operates on an OS/2 server. For companies that choose OS/2 as their client-server platform, LAN Server makes a good choice. It is the success of OS/2 as an application-server platform that has led to the success of LAN Server 4.0. [Ref. 49] IBM is trying to break out of its market niche of OS/2 users with an easier to use product that has a fancier GUI [Ref. 43], but its performance is consistently behind that of both Windows NT and NetWare. [Ref. 49]

### 4. Banyan Vines 5.54

The Virtual Network System, known as VINES, has traditionally been a strong tool for managing global resources on a large network with multiple servers and WAN links. It consists of a strong set of Enterprise Network Services, which include network management, network security, and a global directory service named StreetTalk III. [Ref. 50] StreetTalk was the first global directory service to emerge in the NOS market. It uses a hierarchical three-part naming structure that efficiently and logically defines network objects in a format that is easy to use and remember. It makes identifying and changing users and network resources throughout the enterprise simple and convenient. [Ref. 50] While VINES is a competitive product, it will primarily appeal to existing Banyan shops.

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[2] Comparing costs between Windows NT and NetWare is a difficult task. Both vendors' advertising makes their product seem less expensive than the other. There can also be hidden costs, such as investments already made in training users on the organization's current NOS. The network manager must "shop around" for discounts or packages that may be tailored for their organization. [Ref. 48]

### 5. Implications for CWD

CWD is currently operating NetWare 3.11 on its servers with initial plans to upgrade to NetWare 4.1. [Ref. 17, 19] Several other NSWC PHD LANs either operate or are planning to upgrade to Windows NT, however. The systems are compatible, but CWD should review both NOSs before making any decision to upgrade. Because CWD is not an OS/2 organization nor does it currently support any versions of Banyan, it is not likely that it would gain any benefit from migrating to either of these two products. For CWD's configuration, NetWare or Windows NT will provide the best option for a NOS.

## E. TRANSMISSION MEDIA

Computer networks are either a wire-based or wireless network. Because NSWC PHD conducts a number of important radar and electronics tests, wireless transmission is not an option for CWD's future network. [Ref. 18] Additionally, CWD wants to upgrade to some form of 100Mbps network technology, which can only be supported by the higher-end cabling options. Depending upon the technology choice, the supporting cable must be one of the following: Category 3, 4, or 5 UTP, Type 1 STP, 62.5 micron multimode fiber, or 8 micron single-mode fiber. In selecting the appropriate cable to support a computer network, the following factors must be taken into consideration: [Ref. 36]

1. type of network you plan to create
2. the amount of money available for the network
3. the existing cabling resources
4. building or other safety codes
5. capability to support upgrades to the network.

CWD currently supports a mixture of cable types. Primarily Category 3 UTP with some STP is used from the user workstations to the Cabletron smart hubs. The smart hubs and servers are connected with 50 micron fiber optic cable. [Ref. 18] While this cabling architecture is suitable for the current network configuration, if CWD plans to upgrade to a higher data-rate network that will support its growing and changing needs, it will need to recable at least portions of its current architecture.

At a minimum, Category 5 UTP is specified for frequencies up to 100 MHz. It is intended for voice and data transmission rates up to 100Mbps. Category 3 UTP is only specified for frequencies up to 16 MHz, supporting rates up to 10Mbps (designed for IEEE 802.3 Ethernet/10BaseT) and Category 4 UTP is only specified for frequencies up to 20 MHz, supporting rates up to 16Mbps (designed for IEEE 802.5/token ring). [Ref. 35]

Type 1 STP provides some advantages over UTP varieties in that its shielding reduces interference and minimizes crosstalk between pairs. It can transmit at high data rates and is certified for plenum use, meaning it meets certain fire-safety requirements. Its disadvantages, however, include that it is relatively expensive, bulky, and difficult to use. [Ref. 36]

The characteristics of different types of fiber optic cables are discussed in Appendix E, FDDI. While it provides the greatest capacity, its costs requires an organization to examine whether or not installing fiber is really necessary. A large portion of the cost to recable is simply that of laying the cable, regardless of whether it is UTP, STP, or fiber. If an organization's network is a critical resource that will be upgraded as technologies change, it might be advantageous to install fiber now, before its capabilities are required, in order to save costs in the long run.

Before making any decisions to upgrade the cabling system of the network, CWD should investigate whether or not network drivers are available for the chosen LAN technology and transmission medium. Without doing this, the results could be a network that is not compatible with the new cabling architecture. CWD should also consider

creating a prototype to test its cable upgrade choice before devoting a lot of resources to purchase something that has not been tested.

CWD is one such organization whose network is a critical resource. It already has a requirement for high-speed and flexible bandwidth to the desktop. The high-end engineering applications are already taxing the network. Independent of the technology selected to support the future architecture of CWD's networks, it is highly likely that Category 5 UTP will be the *minimum* required cable to support such an architecture. This means that CWD will have to expend resources to recable. CWD should not, therefore, install the minimum upgrade requirements, but should conduct a cost-benefit analysis to determine which cable provides the best alternative to their unique situation.

## F. MANAGEMENT TOOLS

One of the most important components of any computer network are the tools with which to manage it. Today's network operating systems include basic server management tools, but additional third-party products can be used to enhance the already existing capabilities. For example, a typical NOS includes disk partitioning and security, but third-party management tools extend these features by allowing users to acquire, analyze, and present the information the NOS collects. [Ref. 51]

Management software provides more than statistical information. It can monitor software and devices, notify network administrators when something goes wrong, and aid them in capacity planning and network tuning. All of this can be done locally or remotely. [Ref. 51] Beyond the domain of NOS server management, software packages can manage other aspects of the network, such as, workstation software and hardware, software and hardware inventory, software distribution, application services, and hubs and routers.

CWD currently uses a network analyzer , but because it is used by strictly one network maintainer (there is no one person assigned the responsibility of LAN administrator), it is unclear how effective this tool is. [Ref. 17] The features of

management software reduce the amount of administrative help required by a LAN administrator and improve end-user support. These tools, therefore, should be more effectively implemented by CWD in maintaining its network.

Another type of tool to assist the LAN administrator is computer network simulation software. The insights provided by simulation software generally falls into one of four categories. First, it allows network administrators to accurately assess the end-to-end performance of business-critical applications. This includes the effects on the network from the expanding user population or adding new applications. Second, it provides accurate planning and scalability analysis based on real-life measurements rather than the experience of the network maintainers. Third, the LAN administrator can create a software prototype of anticipated changes to the network. This allows him or her to see the effects of these changes before having to commit large amounts of resources. Finally, simulation software allows designers and administrators to optimize cost/performance factors. [Ref. 52]

This type of tool allows network administrators to better prepare for the future while working with the present network. It contributes to more accurate planning efforts that will more efficiently use an organization's resources. CWD could benefit from the use of such a tool in the current project of upgrading its network. It could continue to receive benefits from simulation software by modeling changes before actual resources must be spent.

## G. NETWORK COMPONENTS NOT DISCUSSED

In limiting our evaluation to a manageable level for a thesis study, we eliminated certain components of a computer network from our research. Such components are required to have a functioning network, but an independent research project would have been conducted for each. We eliminated network protocols from our research because there are too many protocols to be examined and many are largely dependent upon the

network technology to be used. Protocols that are specific to the LAN technologies addressed are discussed in Appendices D through F.

Applications software is a major concern for CWD. As discussed in the baseline characterization, CWD currently has many redundant software capabilities. Simplifying the network in the future will require that CWD streamline these programs and eliminate unnecessary redundancy. DoD will dictate standards for many such programs, for example JCALS and JEDMICS, which require further study by CWD to make informed decisions regarding its applications software.

Finally, hardware is another requirement for CWD's future network which is not addressed here. Again, there are so many options, many of which are dependent upon the networking technology to be chosen, that these issues cannot be addressed under this project.

## H. CONCLUSIONS

In this chapter, we have presented many of the capabilities that will be available to CWD in the year 2000. We focused on a specific set of required network components in order to make this a manageable project. Our focus included: LAN technology (expanded in Appendices D through F), broadband technology, network operating systems, transmission media, and network management tools. The topic we chose not to evaluate due to scope and time constraints were networking protocols, applications software, and hardware.

In Chapter VIII, Conclusions and Recommendations, we combine our anticipated network requirements and future capabilities to form a set of long-term recommendations for defining CWD's target computer network.

# VIII. CONCLUSIONS AND RECOMMENDATIONS

## A. OVERVIEW

This thesis outlines our work. The main body contains eight chapters. A brief review of these chapters follows:

1. In Chapter II, "Methodology," we describe our model of the ideal computer network and discuss how we applied this model to the development of the baseline characterization and target definition methodologies.

2. In Chapter III, "Baseline Environment," we examine the work organization, information, and applications. From this examination, we draw conclusions about the current requirements.

3. In Chapter IV, "Baseline Network," we examine the networking suite. From this examination, we draw conclusions about the current capabilities.

4. In Chapter V, "Baseline Evaluation," we compare the requirements and capabilities to produce our evaluation of the baseline system.

5. In Chapter VI, "Target Environment," we examine trends in private industry, DoD, and the Cruise Weapons community. From this examination, we draw conclusions about the anticipated requirements.

6. In Chapter VII, "Target Evaluation," we examine emerging technologies. From this examination, we identify the capabilities that may play a role in helping CWD meet its anticipated requirements.

7. In Chapter VIII, "Conclusions and Recommendations," we review our findings and present a set of short-term and long-term recommendations for improving CWD's computer network. We finish by discussing the research that must be conducted in order to complete the next step of the TAFIM process.

Our research efforts were structured around helping CWD develop a computer network for the Cruise Weapons community as part of its Engineering 2000 project. We focused on CWD and its network as a prototype for all the elements in the "enterprise." Specifically, CWD has asked us to answer the following research questions:

1. What are our current requirements?
2. What are our current capabilities?
3. Do our current capabilities support our current requirements?
4. What are the anticipated future requirements for the year 2000?
5. What capabilities will be available in the year 2000?
6. How can we incorporate these capabilities to meet our anticipated requirements?

## B. CONCLUSIONS

### 1. Summary

Our conclusions are broken into two categories: the baseline network and the target network.

### 2. The Baseline Network

CWD requires a network that can help it interconnect entities and geographic locations, meet human needs, contend with political and cultural factors, maintain information flows, replace or supplement various exchange media, and support applications. These requirements are driven by the needs of the environment.

CWD has a networking suite that includes a LAN, a backbone, three dial-up networks, and three WAN's. This complex suite provides a set of capabilities. These capabilities satisfy <u>some</u> of the department's functional requirements.

There are significant gaps between the requirements and capabilities. First, the network does not provide sufficient <u>reach</u> (*e.g.*, It does not support the relationships that exist between CWD and most of its customers.). Second, it does not provide sufficient <u>range</u> (*e.g.*, It fails to give customers the ability to receive product information). Third, it does not provide sufficient <u>responsiveness</u> (*e.g.*, The backbone is slow and prone to failure). Fourth, it does not provide adequate <u>user support</u> (*e.g.*, Technicians have little time to devote to end-user training and assistance.). Fifth, it does not provide adequate <u>workgroup support</u> (*e.g.*, Most branches do not have peer-to-peer network operating systems). Sixth, it is too <u>complex</u> (*e.g.*, It has a complicated set of cabling, user nodes, operating systems, network operating systems, WAN's, dial-ups, and supported applications). Finally, it has inadequate levels of <u>maintenance and management</u> (*e.g.*, The department does not have sufficient tools, documentation, policies, entities, or training programs).

### 3. The Target Network

The final three research questions deal specifically with trying to define aspects of CWD's target computer network. To anticipate the future requirements for CWD's network in the year 2000, we examined networking trends in industry to better understand what concepts have a high probability of affecting future networks. Predicting the future is not an exact science, but by understanding what researchers and industry "players" consider to be important today, we can gain insight into what lies ahead.

To better understand what capabilities will be available to organizations in the year 2000, we examined several components of networking. For each component, there are various options that will be available to organizations both today and in the future. For example, under the component LAN technologies, we examined three promising options, Ethernet, FDDI, and ATM. Choosing and applying the best option for each network component to the CWD situation will be key to the network design.

Finally, we tie together the anticipated future requirements and the future capabilities in our recommendations. First, CWD's future network must support both isochronous data as well as the transfer of larger documents. Second, CWD must make major improvements to its LAN, specifically, choosing to migrate to a higher-speed LAN technology capable of support its various needs. Third, CWD will need to recable its network in order to support faster data rates. Fourth, CWD should reduce the complexity of its network, streamline its applications suite, and take advantage of groupware products for project management and coordination. Finally, CWD must create an Information Systems Staff composed of sufficiently educated and trained personnel who manage the IS resources as their primary duty. These long-term recommendations are meant to help move CWD's computer network from the existing state to the desired state.

## C. RECOMMENDATIONS

### 1. Summary

We have divided our recommendations into two subsets. The short-term recommendations are those that CWD can begin to implement today. They involve better usage of resources currently available. The long-term recommendations are those that typically require more planning and financial support. They, therefore, must be accomplished over a greater period of time.

### 2. Short-Term Recommendations

By implementing the following recommendations, CWD can improve its reach, range, responsiveness, user support, workgroup support, maintenance, and management. Each of these recommendations deals with near-term, relatively inexpensive actions that can be taken with minimal external support.

1. CWD should make a strategic decision concerning the long-term direction of the networking suite. This decision involves the classic "make versus buy" problem. On one hand, the department can procure its own external communications services.[1] This option is relatively expensive, but it can lead to improved performance. On the other hand, the department can continue to rely on the AIS Department to provide wide area connectivity. This option is relatively inexpensive, but it yields no near-term performance improvements. We recommend that CWD select the first option.[2] In order to produce the

[1] The procurement sources can be military or civilian. CWD can, for example, work with the Navy's DISN/NAVNET-IP team, a telephone company, or a local Internet service provider. We recommend that CWD select a military source. This way, the department can be reasonably confident that it will comply with DoD standards and have the ability to communicate with other military organizations.

[2] The external communications services are strategic assets. The department depends on these assets to transport inputs from suppliers and deliver outputs to customers. Therefore, it should dedicate the resources (money and labor) needed to produce good performance.

required level of performance, the department should procure its own services.

2. If CWD decides to procure its own services, it should consider using the Navy Terminal Access Program (NAVTAP). This program is managed by the Naval Computers and Telecommunications Station in Pensacola, Florida. It provides dedicated or dial-up access to DISN/NAVNET-IP, MILNET, and the Internet. The dedicated service costs $717/month for 19.2 kbps access and $1900/month for 56 kbps access. The dial-up service costs $75 (one-time charge) plus $30/month for 9.6 kbps access [Ref. 16].

3. CWD should implement its existing copy of *Lotus Fax Server*. By so doing, it can incorporate fax capabilities into its existing network suite. This will expand the range of the network (Reference pp.63, 98, 101).

4. CWD should implement its existing copy of *cc:Mail for Unix*. By so doing, it can give all user nodes full and equal access to the community's standard mail system. This will expand the range of the network and, if accompanied by the removal of *Open Mail* and *Sun Mail*, decrease the level of complexity (Reference pp.65, 100, 101).

5. CWD should give Harpoon divisions access to the applications stored on *CW1*. This can be accomplished by increasing the size of *CW1*'s user base or by employing an existing PC to host a third *NetWare* server.[3] By providing this expanded access, the department will increase the range of its network (Reference pp.65, 89, 101).

[3] *CW1*'s administrator plans to migrate from the Compaq 486 to a Compaq Pentium. The old platform can easily become the host for a third *NetWare* server.

6. CWD should work with the AIS Department to find a near-term solution to the IP address allocation problem. NSWC PHD needs an allocation scheme that can support logical subnetworking and improve performance. With such a scheme, the users should see an increase in the backbone's level of responsiveness (Reference pp.66, 74, 101).

7. CWD should work with the AIS Department, CBC, and TWCS-SEIA to upgrade the TEXN connection. The current system relies on CWD's terminal servers, the LAN, the backbone, NSWC PHD's terminal server, and 9.6 kbps modems. The AIS Department and CBC should provide a simpler and more reliable means for accessing the telephone system.[4] TWCS-SEIA should provide support for faster modem connections (Reference pp.78, 80, 94, 101).

8. CWD should work with AIS Department and TWCS-SEIA to establish a high speed, TCP/IP connection for *cc:Mail*. If the demand for E-mail services continues to grow at its current rate, the 28.8 kbps, dial-up line will become overwhelmed before the year 2000. By replacing this line with a TCP/IP connection, the department can avoid this unpleasant situation and maintain the high level of service[5] (Reference pp.79, 86, 101, and Appendix B).

9. CWD should establish a formal training program for the user community. This program should incorporate basic, intermediate, and advanced lesson plans (taught by the in-house technicians) that are tailored to meet the unique needs of each user group. It should work with new and old employees to ensure that all personnel have the skills needed to perform their jobs

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[4] In the current system, a PC accesses the public telephone system through a local terminal server, the LAN, the brouter, the backbone, NSWC PHD's terminal server and modem pool, and CBC's local telephone system. This complex chain has too many potential bottlenecks and single points of failure. It would be more effective if users could access the telephone system directly (like they do for voice communications).

[5] If CWD elects to continue using the TCP/IP services provided by the AIS Department, this move should involve no additional costs. If CWD elects to purchase its TCP/IP services from another source (*e.g.*, NAVTAP), it will have to conduct a full cost-benefit analysis before implementing this recommendation.

effectively (*e.g.*, Many employees need to understand the procedures for using *cc:Mail* to transfer formatted documents.) (Reference pp.30, 31, 69, 95, 102).

10. CWD should expand its use of *Windows for Workgroups*. This peer-to-peer network operating system supports the sharing of files, printers, and other resources. It can be an invaluable asset within a branch workgroup. By starting with the divisions and branches that already have this system, the department should build a networking environment that incorporates the peer-to-peer capabilities of *Windows for Workgroups* and the dedicated server capabilities of *NetWare* (Reference pp.34, 66, 70, 87, 96, 102).

11. CWD should make better use of its *OpenView* implementation. With the right hardware, this system could serve as the centerpiece of an effective network operations center (Reference pp.68, 95, 102).

12. CWD should establish formal maintenance and management policies. These policies should cover such areas as back-up scheduling, planned maintenance, corrective maintenance, documentation requirements, and training requirements[6] (Reference pp.67-69, 95, 102).

13. CWD should maintain accurate and complete documentation. This documentation should cover the cabling plant and the locations and purposes of each network component. It should be written with the assumption that the reader is totally unfamiliar with the system (Reference pp.67-69, 95, 102) .

14. CWD should establish a network operations center. This center should be staffed during regular working hours. It should serve as the focal point for

[6] *Novell's Guide to NetWare 3.12 Networks* provides excellent source material for developing general maintenance and management policies. DoN-specific guidance can be found on the World Wide Web at

planned maintenance, corrective maintenance, user registration, user assistance, and status reporting. Furthermore, it should have the ability to work with the AIS Department and other service providers to resolve problems and maintain network integrity (Reference pp.67-69, 95, 102).

### 3. Long-Term Recommendations

The following long-term recommendations are provided to help CWD determine what its target network architecture will be and how to improve from its baseline architecture to this desired future state.

1. Regarding the concern of <u>reach</u>, CWD must continue to re-evaluate its decision for the organization to operate over DOD WAN connectivity, such as DISN, or establish and finance its own connectivity. Because these external communications are not maintained by CWD and they may become insufficient to support CWD's needs, there may be a legitimate future need to maintain external communications. CWD should also consider both access to other Navy and DoD networks that could provide the required support and the option of maintaining the status quo for external communications, expecting these networks to upgrade with the changing technologies. (Reference pp. 81-82, 121-124)

2. CWD needs to improve its *range* capabilities to <u>support more remote services</u>. Workers need to have the flexibility to function outside the office with the same access to applications and information that they have while in the office. Enhancing the dial-up capabilities will help improve reach to mobile employees. (Reference pp. 78, 104, 112-113)

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*http://204.222.128.911, http://www.nps.navy.mil/internal/policy, and http://dubhe.cc.nps.navy.mil/~peprotac/security/navigator.html.*

3. The network must be capable of handling isochronous data, such as digitized voice and video. The support for both the traditional textual forms of data (not as time sensitive) and the more dynamic forms of data is a requirement for the design of CWD's target network. Additionally, the network must be able to handle the transfer of larger documents to support CWD's technical manual publication functions. This requires flexible speed and bandwidth as well as support for different types of data. A recommendation for how to accomplish this is addressed next. (Reference pp. 105-106)

4. CWD should become fully integrated with NSWC PHD's Paperless Environment Project which will provide complete access to the Defense Messaging System. (Reference p. 96)

5. To be able to support some of the above recommendations, CWD must make major improvements to its LAN. This one aspect is very important, because it will form the cornerstone for the rest of CWD's future network. We have outlined the most promising options in Appendices D through F. While ATM is a very promising alternative, it is very risky due to its high expense and the "newness" of the technology. We do not anticipate that it will be ready for implementation by the year 2000. Of the remaining options, we recommend that CWD conduct a cost-benefit analysis of Switched Ethernet and FDDI. While FDDI provides greater capabilities and it will interface well with the NSWC PHD FDDI campus backbone, it is a degree of magnitude more expensive than other options. Switched Ethernet provides an increase from the current LAN capabilities and its primary advantage is the flexibility to incrementally upgrade. It does not, however, provide dedicated bandwidth which will be necessary in implementing CAD/CAM programs and supporting engineering drawings and isochronous forms of data. Financial

concerns aside, today, FDDI provides the best support to CWD's LAN needs. (Reference Appendices D through F)

6. To support faster speeds and newer technologies, CWD must recable its network. This is highly dependent upon the selected LAN technology. Because a large portion of the expense in recabling is independent of the form of cable to be installed, CWD should install cable that will be able to support upgrades made to the network. If economically feasible, we recommend 62.5 multimode fiber, but at a minimum Category 5, UTP. A cost-benefit analysis is recommended to when selecting the new cable to install. It may prove beneficial for CWD to install single-mode fiber at the same time as the multimode fiber in anticipation of future requirements. (Reference pp. 129-131)

7. To improve workgroup support in the future, groupware products may provide an effective means of managing projects and coordinating team efforts over differing time and place constraints. CWD should consider this type of software support for the future. Lotus Notes is a popular groupware product capable of providing this type of support. (Reference pp. 104, 109)

8. To reduce the complexity of CWD's network, it should consider the option of using JCALS to support the current functions provided by EDN. This would allow them to remove the Sun Workstations whose major function is to support this one, albeit very important, application. More importantly, JCALS would give the department a way to break the "paper paradigm" and deliver electronic technical manuals to the customers. CWD must expect some user resistance to such a change, but through a strong training program and command support such a migration will be possible. (Reference pp. 66, 78, 91, 99-101)

9. Although many departments at NSWC PHD may move to Windows NT as their network operating system, CWD has been using Novell NetWare and we recommend that it continue to do so. Both are outstanding products, but once established with NetWare 4.1, there is no compelling reason for CWD to migrate to a Windows NT supported LAN. (Reference pp. 125-129)

10. One of the shortfalls of the current network as discussed in Chapter 4 is the complexity of the current applications suite. In order to more effectively manage its network in the future, it will be critical for CWD to streamline its applications suite.[7] There are many unnecessary redundant capabilities, such as multiple document management application, and platforms that support a single function, such as EDN. These are the types of problems that need to be eliminated. Determining and enforcing a departmental policy will help to accomplish this type of streamlining. (Reference pp. 57-60)

11. CWD already considers its computer network to be a critical component to its effective operation. Therefore, it must dedicate the appropriate resources to maintain such an important feature. This means dedicating personnel to form an Information Systems Staff where their *primary* responsibilities are to IS concerns, rather than someone who attends to these matters as a co-lateral duty. These people must have the appropriate education and training to implement the department's IS services. Their responsibilities should include developing departmental IS policies, installing new equipment, staffing the Network Operations Center, maintaining appropriate network documentation, and establishing a strong training program for *everyone* in the CWD organization. The requirement for establishing a training program cannot be understated. It is critical that both those maintaining the resources as well as those using the resources receive the appropriate education and training.

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[7] As a side-note, streamlining the operating system suite is dependent upon streamlining the applications suite.

Studies have shown that organizations serious about developing good IS programs typically spend two weeks per person per year for IS training. [Ref. 63] (Reference pp. 68-70)

12. To assist the management and maintenance effort, CWD should consider the option of acquiring additional software management or simulation tools. These will help to maintain network components before equipment fails and to show how changes will effect the network before finances are committed. Some possible examples include *COMNET III*, *GrafNet Plus*, and *OpenView*. (The Windows version is already maintained by CWD.) (Reference pp. 131-132)

13. Whatever changes are selected, CWD should construct a prototype of the future network in order to test the system as a whole. This should be done before resources are devoted to procuring the various components of the new network in order to prevent CWD from spending large amounts of money on a system that may not operate correctly. (Reference pp. 130)

## D. RECOMMENDATIONS FOR FURTHER STUDY

Our project focused on the characteristics of CWD's baseline and target networks. A follow-on project should focus on the plan for migrating from the baseline state to the target state. The migration plan should describe and prioritize the required projects (*e.g.*, incorporating Switched Ethernet technology in the LAN). Then, it should identify each project's costs, benefits, milestones, and measures of success. Finally, it should address the anticipated affects on network operations, other departmental functions, and key external entities. To define such a plan, researchers must answer the following questions:

1. Which projects must be included in the migration plan?[8]
2. What is the relative priority of each project?
3. What are each project's tangible and intangible costs?
4. What are each project's tangible and intangible benefits?
5. What are each project's start times, stop times, and other milestones?
6. How should the department measure the success of each project?
7. How will the migration plan affect network operations?
8. How will the migration plan affect other departmental functions?
9. How will the migration plan affect the customers and suppliers?
10. How will the migration plan affect the seniors, peers, and subordinates?

[8] Many of these projects are identified in our short-term and long-term recommendations.

# APPENDIX A. LAN USAGE PATTERNS

## A. INTRODUCTION

In March 1995, CWD used a protocol sniffer to capture and record LAN utilization levels at thirty second intervals. We used this data to help us answer the following questions:

1. Are the weekdays and working hours significantly busier than the weekends and non-working hours?
2. Are there significant differences among the individual days of the week and hours of the day?
3. What is the "typical" range of utilization levels?

## B. WEEKDAYS VS. WEEKENDS, WORKING HOURS VS. OFF HOURS

CWD collected 89280 data elements (31 days x 2880 recordings per day). We reduced this data set and used it to construct Table 3. This table depicts the mean utilization levels for the seven days of the week and the twenty-four hours of the day.

| Start | Stop | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|---|
| 00:00 | 01:00 | 0.71% | 0.57% | 1.00% | 3.53% | 2.79% | 0.58% | 0.68% |
| 01:00 | 02:00 | 0.67% | 0.58% | 0.76% | 0.62% | 0.72% | 0.54% | 0.64% |
| 02:00 | 03:00 | 0.66% | 0.59% | 0.63% | 0.67% | 0.69% | 0.55% | 0.68% |
| 03:00 | 04:00 | 0.64% | 0.58% | 0.54% | 0.55% | 0.63% | 0.50% | 0.69% |
| 04:00 | 05:00 | 0.61% | 0.63% | 0.52% | 10.90% | 0.65% | 0.49% | 0.70% |
| 05:00 | 06:00 | 0.93% | 0.69% | 0.75% | 12.73% | 0.65% | 0.60% | 1.03% |
| 06:00 | 07:00 | 5.13% | 1.61% | 2.21% | 7.19% | 2.07% | 1.05% | 0.68% |
| 07:00 | 08:00 | 8.25% | 8.73% | 6.65% | 21.08% | 4.88% | 1.58% | 0.75% |
| 08:00 | 09:00 | 9.19% | 11.41% | 9.06% | 9.86% | 6.93% | 1.26% | 0.81% |
| 09:00 | 10:00 | 9.40% | 9.52% | 12.29% | 8.43% | 7.71% | 1.42% | 0.81% |
| 10:00 | 11:00 | 11.89% | 12.14% | 9.97% | 10.03% | 7.06% | 1.33% | 0.73% |
| 11:00 | 12:00 | 7.97% | 5.91% | 8.14% | 9.60% | 5.82% | 1.09% | 1.19% |
| 12:00 | 13:00 | 8.08% | 9.07% | 9.37% | 9.04% | 6.42% | 1.20% | 0.97% |
| 13:00 | 14:00 | 8.76% | 8.32% | 8.61% | 9.18% | 10.96% | 1.59% | 0.65% |
| 14:00 | 15:00 | 9.62% | 12.29% | 8.74% | 10.00% | 11.97% | 1.65% | 0.73% |
| 15:00 | 16:00 | 7.98% | 12.84% | 7.68% | 7.55% | 5.53% | 1.17% | 0.79% |
| 16:00 | 17:00 | 5.70% | 6.35% | 4.94% | 5.04% | 5.09% | 0.84% | 1.94% |
| 17:00 | 18:00 | 3.63% | 2.03% | 2.02% | 2.71% | 1.68% | 1.02% | 0.74% |
| 18:00 | 19:00 | 1.34% | 6.18% | 0.93% | 9.85% | 1.21% | 0.61% | 0.63% |
| 19:00 | 20:00 | 0.64% | 6.10% | 0.68% | 2.82% | 0.62% | 0.61% | 0.76% |
| 20:00 | 21:00 | 0.57% | 0.55% | 0.57% | 0.65% | 0.73% | 0.68% | 0.92% |
| 21:00 | 22:00 | 0.60% | 0.74% | 0.61% | 0.60% | 0.73% | 0.65% | 0.65% |
| 22:00 | 23:00 | 2.38% | 0.65% | 0.70% | 0.69% | 0.73% | 0.74% | 0.83% |
| 23:00 | 00:00 | 0.57% | 0.50% | 3.92% | 1.63% | 1.46% | 0.61% | 0.73% |

**Table 3. Utilization Levels (March 1995 Baseline)**

After constructing Table 3, we calculated two sets of descriptive statistics. In the first, we looked at the data as a function of the day of the week. In the second, we looked at the data as a function of the time of day. The key statistics are recorded in Tables 4 through 7.

| Parameter | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| Mean | 4.41% | 4.94% | 4.22% | 6.46% | 3.65% | 0.93% | 0.82% |
| Standard Deviation | 3.96% | 4.60% | 4.00% | 5.17% | 3.48% | 0.39% | 0.27% |
| Minimum Value | 0.57% | 0.50% | 0.52% | 0.55% | 0.62% | 0.49% | 0.63% |
| Maximum Value | 11.89% | 12.84% | 12.29% | 21.08% | 11.97% | 1.65% | 1.94% |

**Table 4. Descriptive Statistics (By Day of Week)**

| Parameter | 00-01 | 01-02 | 02-03 | 03-04 | 04-05 | 05-06 | 06-07 | 07-08 | 08-09 |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 1.41% | 0.65% | 0.64% | 0.59% | 2.07% | 2.48% | 2.85% | 7.42% | 6.93% |
| Standard Deviation | 1.22% | 0.08% | 0.05% | 0.07% | 3.89% | 4.52% | 2.40% | 6.77% | 4.24% |
| Minimum Value | 0.57% | 0.54% | 0.55% | 0.50% | 0.49% | 0.60% | 0.68% | 0.75% | 0.81% |
| Maximum Value | 3.53% | 0.76% | 0.69% | 0.69% | 10.90% | 12.73% | 7.19% | 21.08% | 11.41% |

**Table 5. Descriptive Statistics (By Time of Day, 0000 to 0800)**

| Parameter | 09-10 | 10-11 | 11-12 | 12-13 | 13-14 | 14-15 | 15-16 | 16-17 | 17-18 |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 7.08% | 7.59% | 5.68% | 6.31% | 6.87% | 7.86% | 6.22% | 4.27% | 1.97% |
| Standard Deviation | 4.32% | 4.78% | 3.36% | 3.70% | 4.03% | 4.73% | 4.21% | 2.05% | 0.98% |
| Minimum Value | 0.81% | 0.73% | 1.09% | 0.97% | 0.65% | 0.73% | 0.79% | 0.84% | 0.74% |
| Maximum Value | 12.29% | 12.14% | 9.60% | 9.37% | 10.90% | 12.29% | 12.84% | 6.35% | 3.63% |

**Table 6. Descriptive Statistics (By Time of Day, 0900 to 1700)**

| Parameter | 18-19 | 19-20 | 20-21 | 21-22 | 22-23 | 23-24 |
|---|---|---|---|---|---|---|
| Mean | 2.96% | 1.75% | 0.67% | 0.65% | 0.96% | 1.35% |
| Standard Deviation | 3.62% | 2.08% | 0.13% | 0.06% | 0.63% | 1.22% |
| Minimum Value | 0.61% | 0.61% | 0.55% | 0.60% | 0.65% | 0.50% |
| Maximum Value | 9.85% | 6.10% | 0.92% | 0.74% | 2.38% | 3.92% |

**Table 7. Descriptive Statistics (By Time of Day, 1800 to 2300)**

Next, we graphed the mean utilization levels. By so doing, we hoped to gain a better appreciation for the distribution of data over the "day of the week" and "time of day" domains. Figure 30 depicts the mean as a function of the day of the week. Figure 31 depicts the mean as a function of the time of day.

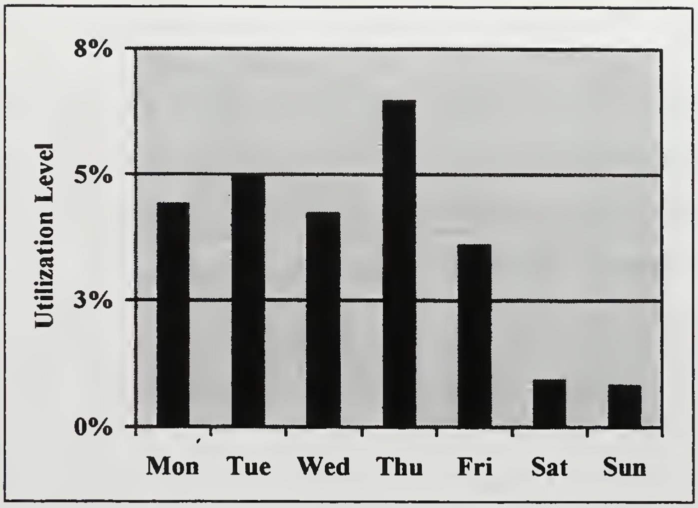


**Figure 30. Mean Utilization Levels (By Day of Week)**

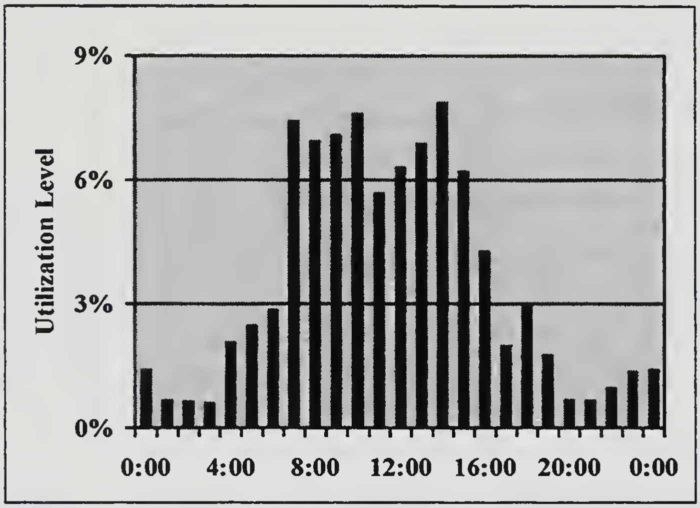


**Figure 31. Mean Utilization Levels (By Time of Day)**

After examining Figures 30 and 31, we made the following observations: (1) the weekday levels appeared to be significantly larger their weekend counterparts, and (2) the 0700 to 1700 (working hours) levels appeared to be significantly larger than their 1700 to 0700 (after hours) counterparts. We pursued these observations by constructing and executing two tests of hypotheses.

To prepare for the first hypothesis test, we reduced the data into two sets. One contained the mean weekday readings, and the other contained the mean weekend readings. Both of these sets are depicted in Table 8.

| Start | Stop | Weekdays | Weekends |
|---|---|---|---|
| 00:00 | 01:00 | 1.72% | 0.63% |
| 01:00 | 02:00 | 0.67% | 0.59% |
| 02:00 | 03:00 | 0.65% | 0.61% |
| 03:00 | 04:00 | 0.59% | 0.60% |
| 04:00 | 05:00 | 2.66% | 0.59% |
| 05:00 | 06:00 | 3.15% | 0.82% |
| 06:00 | 07:00 | 3.64% | 0.87% |
| 07:00 | 08:00 | 9.92% | 1.16% |
| 08:00 | 09:00 | 9.29% | 1.03% |
| 09:00 | 10:00 | 9.47% | 1.11% |
| 10:00 | 11:00 | 10.22% | 1.03% |
| 11:00 | 12:00 | 7.49% | 1.14% |
| 12:00 | 13:00 | 8.39% | 1.08% |
| 13:00 | 14:00 | 9.17% | 1.12% |
| 14:00 | 15:00 | 10.53% | 1.19% |
| 15:00 | 16:00 | 8.32% | 0.98% |
| 16:00 | 17:00 | 5.42% | 1.39% |
| 17:00 | 18:00 | 2.41% | 0.88% |
| 18:00 | 19:00 | 3.90% | 0.62% |
| 19:00 | 20:00 | 2.17% | 0.68% |
| 20:00 | 21:00 | 0.61% | 0.80% |
| 21:00 | 22:00 | 0.66% | 0.65% |
| 22:00 | 23:00 | 1.03% | 0.78% |
| 23:00 | 00:00 | 1.61% | 0.67% |

**Table 8. Mean Utilization Levels (Weekdays vs. Weekend**

After reducing the data in this manner, we calculated the descriptive statistics and plotted the means. Table 9 contains the key statistics. Figure 32 depicts the means.

| Parameter | Mondays through Fridays | Saturdays through Sundays |
|---|---|---|
| Mean | 4.74% | 0.88% |
| Standard Deviation | 3.76% | 0.24% |
| Minimum Value | 0.59% | 0.59% |
| Maximum Value | 10.53% | 1.39% |

**Table 9. Descriptive Statistics (Weekdays vs. Weekend)**

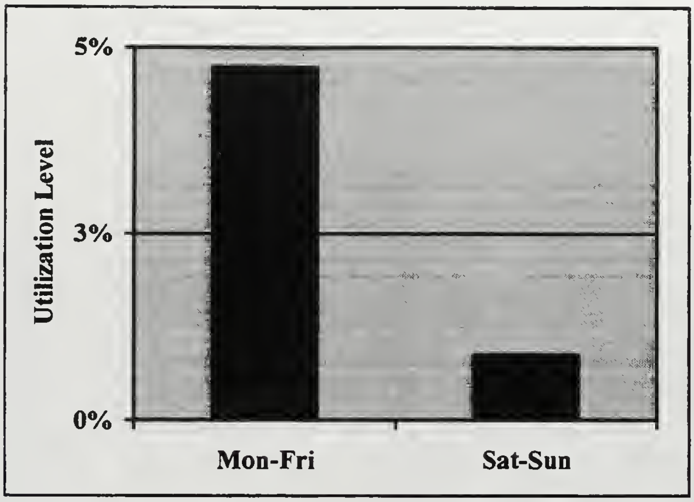


**Figure 32. Mean Utilization Levels (Weekdays vs. Weekends)**

Figure 32 appeared to validate our observation regarding the difference between weekday and weekend utilization levels. After passing this "reality check," we constructed and executed our first hypothesis test. This test is summarized in Table 10.

| | |
|---|---|
| **Key Terms** | $\mu_{mf}$ = Mean network utilization level for the Weekdays; $\mu_{ss}$ = Mean network utilization level for the Weekend |
| **Null Hypothesis** | $\mu_{mf} = \mu_{ss}$; There is no significant difference between the mean utilization levels for the Weekdays and Weekend. |
| **Alternative Hypothesis** | $\mu_{mf} \neq \mu_{ss}$; There is a significant difference between the mean utilization levels for the Weekdays and Weekend. |
| **Statistical Test** | F-Test (2 sample sets, parametric data) |
| **Level of Significance** | $\alpha = 0.05$ |
| **Computed F-Value** | $F = 245.18$ ($p = 0.00$) |
| **Critical Value** | $F_C = 2.01$ |
| **Decision** | $F > F_C$, so we can reject the null hypothesis and conclude that there is a significant difference between the utilization levels |

**Table 10. Hypothesis Test (Weekdays vs. Weekend)**

This test allowed us to conclude that the weekday utilization levels were significantly greater than the weekend utilization levels.

To prepare for the second test, we reduced the data into two sets. One contained the mean 0700-1700 readings, and the other contained the mean 1700-0700 readings. Both of these sets are depicted in Table 11.

| Day of the Week | 0700-1700 | 1700-0700 |
|---|---|---|
| Mon | 8.68% | 1.66% |
| Tue | 9.66% | 1.89% |
| Wed | 8.54% | 1.38% |
| Thu | 9.98% | 4.01% |
| Fri | 7.24% | 1.36% |
| Sat | 1.31% | 0.67% |
| Sun | 0.94% | 0.82% |

**Table 11. Mean Utilization Levels (0700-1700 vs. 1700-0700)**

After reducing the data in this manner, we calculated the descriptive statistics and plotted the means. Table 12 contains the key statistics. Figure 33 depicts the means.

| Parameter | 0700 to 1700 | 1700 to 0700 |
|---|---|---|
| Mean | 6.62% | 1.68% |
| Standard Deviation | 3.86% | 1.11% |
| Minimum Value | 0.94% | 0.67% |
| Maximum Value | 9.98% | 4.01% |

**Table 12. Descriptive Statistics (0700-1700 vs. 1700-0700)**

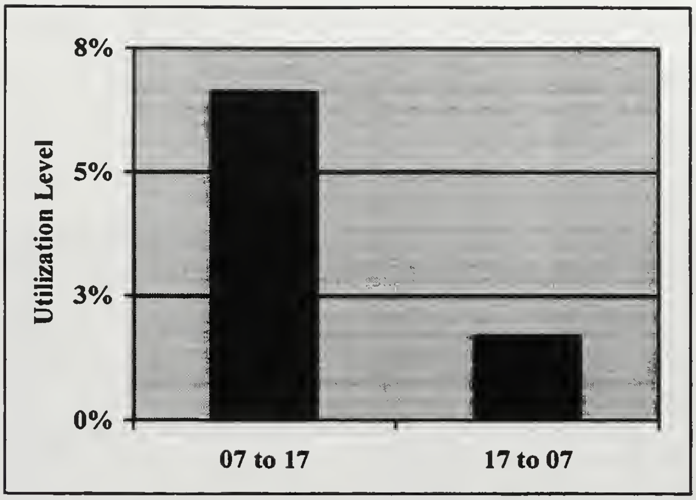


**Figure 33. Mean Utilization Levels (0700-1700 vs. 1700-0700)**

Figure 33 appeared to validate our observation regarding the difference between the 0700-1700 and 1700-0700 utilization levels. After passing this "reality check," we constructed and executed our second test. This test is summarized in Table 13.

| | |
|---|---|
| **Key Terms** | $\mu_{07}$ = Mean network utilization level for the 0700-1700 period; $\mu_{17}$ = Mean network utilization level for the 1700-0700 period |
| **Null Hypothesis** | $\mu_{07} = \mu_{17}$; There is no significant difference between the mean utilization levels for the 0700-1700 and 1700-0700 periods |
| **Alternative Hypothesis** | $\mu_{07} \neq \mu_{17}$; There is a significant difference between the mean utilization levels for the 0700-1700 and 1700-0700 periods |
| **Statistical Test** | F-Test (2 sample sets, parametric data) |
| **Level of Significance** | $\alpha = 0.05$ |
| **Computed F-Value** | $F = 12.02$ ($p = 0.00$) |
| **Critical Value** | $F_C = 4.28$ |
| **Decision** | $F > F_C$, so we can reject the null hypothesis and conclude that there is a significant difference between the utilization levels |

**Table 13. Hypothesis Test (0700-1700 vs. 1700-0700)**

This test allowed us to conclude that the 0700-1700 utilization levels were significantly greater than the 1700-0700 utilization levels.

## C. WORKDAYS AND WORKING HOURS

After drawing our first two conclusions, we constructed Table 14. This table focuses on the five days of the work week and the ten hours of the work day.

| Start | Stop | Mon | Tue | Wed | Thu | Fri |
|---|---|---|---|---|---|---|
| 07:00 | 08:00 | 8.25% | 8.73% | 6.65% | 21.08% | 4.88% |
| 08:00 | 09:00 | 9.19% | 11.41% | 9.06% | 9.86% | 6.93% |
| 09:00 | 10:00 | 9.40% | 9.52% | 12.29% | 8.43% | 7.71% |
| 10:00 | 11:00 | 11.89% | 12.14% | 9.97% | 10.03% | 7.06% |
| 11:00 | 12:00 | 7.97% | 5.91% | 8.14% | 9.60% | 5.82% |
| 12:00 | 13:00 | 8.08% | 9.07% | 9.37% | 9.04% | 6.42% |
| 13:00 | 14:00 | 8.76% | 8.32% | 8.61% | 9.18% | 10.96% |
| 14:00 | 15:00 | 9.62% | 12.29% | 8.74% | 10.00% | 11.97% |
| 15:00 | 16:00 | 7.98% | 12.84% | 7.68% | 7.55% | 5.53% |
| 16:00 | 17:00 | 5.70% | 6.35% | 4.94% | 5.04% | 5.09% |

**Table 14. Network Utilization Levels (Weekdays and Working Hours)**

Next, we calculated two sets of descriptive statistics. In the first, we looked at the data as a function of the day of the work week. In the second, we looked at the data as a function of the hour of workday. The key statistics are recorded in Tables 15, 16, and 17.

| Parameter | Mon | Tue | Wed | Thu | Fri |
|---|---|---|---|---|---|
| Mean | 8.69% | 9.66% | 8.54% | 9.98% | 7.24% |
| Standard Deviation | 1.58% | 2.46% | 1.96% | 4.18% | 2.41% |
| Minimum Value | 5.70% | 5.91% | 4.94% | 5.04% | 4.88% |
| Maximum Value | 11.89% | 12.84% | 12.29% | 21.08% | 11.97% |

**Table 15. Descriptive Statistics (By Day of Work Week)**

| Parameter | 0700-0800 | 0800-0900 | 0900-1000 | 1000-1100 | 1100-1200 |
|---|---|---|---|---|---|
| Mean | 9.92% | 9.29% | 9.47% | 10.22% | 7.49% |
| Standard Deviation | 6.42% | 1.62% | 1.74% | 2.04% | 1.61% |
| Minimum Value | 4.88% | 6.93% | 7.71% | 7.06% | 5.82% |
| Maximum Value | 21.08% | 11.41% | 12.29% | 12.14% | 9.60% |

**Table 16. Descriptive Statistics (By Time of Workday -- 0700 to 1100)**

| Parameter | 1200-1300 | 1300-1400 | 1400-1500 | 1500-1600 | 1600-1700 |
|---|---|---|---|---|---|
| Mean | 8.39% | 9.17% | 10.5347% | 8.32% | 5.42% |
| Standard Deviation | 1.21% | 1.05% | 1.54% | 2.71% | 0.60% |
| Minimum Value | 6.42% | 8.32% | 8.74% | 5.53% | 4.94% |
| Maximum Value | 9.37% | 10.96% | 12.29% | 12.84% | 6.35% |

**Table 17. Descriptive Statistics (By Time of Workday -- 1200 to 1700)**

After constructing these tables, we graphed the means. By so doing, we hoped to gain a better appreciation for the distribution of data over the "day of the work week" and "hour of the work day" domains. Figure 34 depicts the means as a function of the day of the work week. Figure 35 depicts the means as a function of the hour of the work day.

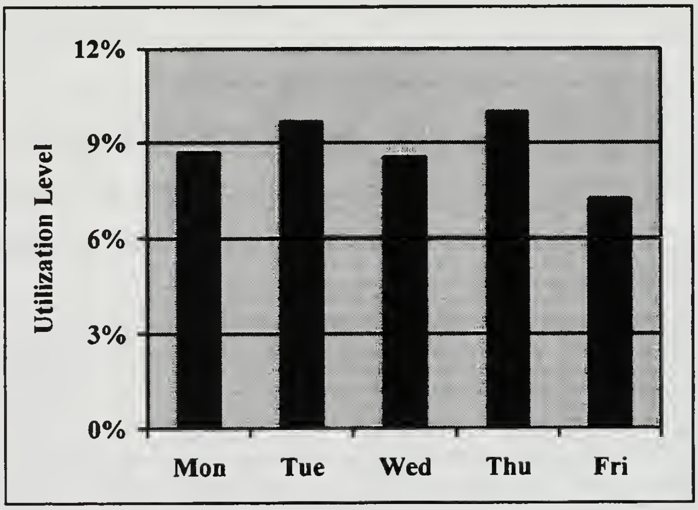


**Figure 34. Mean Utilization Levels (By Day of the Work Week)**

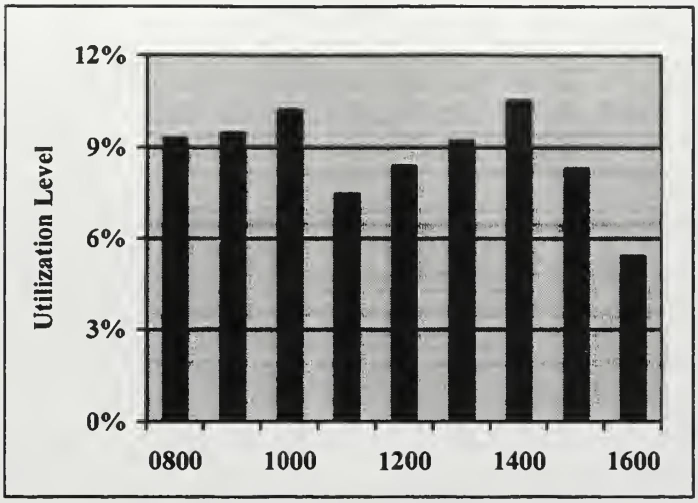


**Figure 35. Mean Utilization Levels (By Hour of the Workday)**

After examining Figures 34 and 35, we made the following observations: (1) there appeared to be significant differences among the utilization levels for the five days of the work week, and (2) there appeared to be significant differences among the utilization levels for the ten hours of the work day. We pursued these observations by constructing and executing two tests of hypotheses.

The first test was constructed to validate our observation concerning the differences among the utilization levels for the days of the work week. Because the data set was already organized in the appropriate manner, we did not need to manipulate it, calculate descriptive statistics, or produce a graph. We, instead, used our existing information as the basis of the hypothesis test. This test is summarized in Table 16.

This results of this test allowed us to conclude that <u>there were no significant differences among the utilization levels for the five days of the work week</u>. This conclusion was surprising, because it contradicted our "gut feeling" and challenged one of CWD's long-held assumptions about its network's operational patterns.[1]

---

[1] CWD focused on maximum and mean utilization levels (without looking at the complete distributions) when it formed the belief that Tuesdays and Thursdays were the busiest days of the work week.

| | |
|---|---|
| **Key Terms** | $\mu_M$ = Mean network utilization level for Mondays (working hours);<br>$\mu_T$ = Mean network utilization level for Tuesdays (working hours);<br>$\mu_W$ = Mean network utilization lvl for Wednesdays (working hours);<br>$\mu_R$ = Mean network utilization level for Thursdays (working hours);<br>$\mu_F$ = Mean network utilization level for Fridays (working hours); |
| **Null Hypothesis** | $\mu_M = \mu_T = \mu_W = \mu_R = \mu_F$; There are no significant differences among the mean utilization levels for the five days of the work week. |
| **Alternative Hypothesis** | $\mu_M \neq \mu_T \neq \mu_W \neq \mu_R \neq \mu_F$ ; There is a significant difference among the mean utilization levels for the five days of the work week. |
| **Statistical Test** | ANOVA (5 sample sets, parametric data) |
| **Level of Significance** | $\alpha = 0.05$ |
| **Computed F-Value** | $F = 1.63$ ($p = 0.18$) |
| **Critical Value** | $F_C = 2.58$ |
| **Decision** | $F < F_C$, so we cannot reject the null hypothesis. There are no significant differences among the utilization levels. |

**Table 18. Hypothesis Test (Days of the Work Week)**

After drawing this conclusion, we turned our attention to the observation concerning the differences among the utilization levels for the ten hours of the work day. In order to validate this observation, we constructed the test summarized in Table 19.

This hypothesis test allowed us to conclude that there were no significant differences among the utilization levels for the ten hours of the work day. This conclusion challenged another one of CWD's long-held assumptions about its network's operational patterns.

| | |
|---|---|
| **Key Terms** | $\mu_{07}$ = Mean network utilization level for 0700-0800 (work days); $\mu_{08}$ = Mean network utilization level for 0800-0900 (work days); $\mu_{09}$ = Mean network utilization level for 0900-1000 (work days); $\mu_{10}$ = Mean network utilization level for 1000-1100 (work days); $\mu_{11}$ = Mean network utilization level for 1100-1200 (work days); $\mu_{12}$ = Mean network utilization level for 1200-1300 (work days); $\mu_{13}$ = Mean network utilization level for 1300-1400 (work days); $\mu_{14}$ = Mean network utilization level for 1400-1500 (work days); $\mu_{15}$ = Mean network utilization level for 1500-1600 (work days); $\mu_{16}$ = Mean network utilization level for 1600-1700 (work days); |
| **Null Hypothesis** | $\mu_{07} = \mu_{08} = \ldots = \mu_{16}$; There is no significant difference among the mean utilization levels for the ten hours of the work day. |
| **Alternative Hypothesis** | $\mu_{07} \neq \mu_{08} \neq \ldots \neq \mu_{16}$; There is a significant difference among the mean utilization levels for the ten hours of the work day. |
| **Statistical Test** | ANOVA (10 sample sets, parametric data) |
| **Level of Significance** | $\alpha = 0.05$ |
| **Computed F-Value** | $F = 1.73$ ($p = 0.11$) |
| **Critical Value** | $F_C = 2.12$ |
| **Decision** | $F < F_C$, so we <u>cannot reject the null hypothesis.</u> There <u>is no significant difference</u> among the utilization levels. |

**Table 19. Hypothesis Test (Hours of the Work Day)**

## D. CONCLUSIONS

Our study of the March 1995 baseline assessment allowed us to draw the following conclusions concerning the LAN usage patterns:

1. The weekdays are significantly busier than the weekends.

2. The 0700 to 1700 period is significantly busier than the 1700 to 0700 period.

3. No workday is significantly busier than any other workday.

4. There is no "busy hour" during the typical workday.

These conclusions can only be applied directly to an analysis of the traffic patterns for March 1995. If, however, we accept CWD's claim that March 1995 was a representative period, we can extend them to apply to a general characterization of the department's networking activity. With this in mind, we decided to characterize the usage patterns by calculating summary statistics from the set of readings for working days and working hours. It was our belief that these figures would represent accurately the utilization levels for the "typical" work hour in the "typical" workday. These figures are contained in Table 20.

| | |
|---|---|
| **Mean** | 8.82% |
| **Standard Error** | 0.39% |
| **Standard Deviation** | 2.74% |
| **Minimum Value** | 4.88% |
| **Maximum Value** | 21.08% |

**Table 20. Workday Utilization Characteristics**

From this table, we concluded that CWD's mean workday utilization level was 8.82% ± 2.74%. This yielded a practical dynamic range of 6.08% to 11.56%. This range was a key component of our baseline evaluation.

# APPENDIX B. CC:MAIL PERFORMANCE

## A. INTRODUCTION

CWD maintains data concerning the flow of traffic between its TIRS server and the *cc:Mail* hub (located in Saint Louis).[1] Key data elements include the numbers of messages, sizes of messages, transmission times, and reception times. These numbers are collected on a weekly basis and recorded in the system administrator's log book.

During our research, we had access to the cc:Mail traffic statistics for September 1994 through September 1995 (with the exception of February 1995).[2] We reduced this data set by summarizing the statistics for each of the represented quarters. Then, we used these summary statistics to help us answer the following questions:

1. How many messages are transmitted and received during the "typical" workday? What are the average sizes of the transmitted and received messages? What is the total daily traffic load?

2. How long does it take to transmit each message to Saint Louis? How long does it to receive each message from Saint Louis? How much time is expended handling the total daily traffic load?

3. How will the daily traffic load change over the next five years? How will the message handling time change over the next five years? Will the forecasted handling time be able to support the forecasted traffic load adequately?

---

[1] In the current configuration, traffic flow is supported by dial-up telephone lines and 28.8kbps modems. CWD would like to change this configuration so that the traffic flow is supported by TCP/IP connections.

[2] The February pages were removed from the log book without the administrator's knowledge or approval.

## B. DAILY TRAFFIC LOAD

After reviewing the log, we learned that CWD transmitted 160 messages and received 106 messages during the "typical" workday in Fiscal Year 1995. The average transmitted message contained 107 kilobits (kb) of data, while the average received message had 106 kb of data. Taken together, the transmitted and received message streams produced a daily traffic load of 29 megabits (Mb). These figures are summarized in Table 21.

| Daily Averages (FY95) | Transmitted | Received |
|---|---|---|
| Number of Messages | 160 messages/day | 106 messages/day |
| Bits per Message | x 107 kb/message | x 106 kb/message |
| Total Load | = 17 Mb/day | = 12 Mb/day |

**Table 21. Daily Traffic Load (Fiscal Year 1995)**

## C. HANDLING TIME

In Fiscal Year 1995, CWD spent 243 transmitting the average bit to Saint Louis and 519 microseconds receiving the average bit from Saint Louis.[3] At these rates, the network could handle the entire daily traffic load in 173 minutes. These figures are summarized in Table 22.

| Daily Averages (FY95) | Transmitted | Received |
|---|---|---|
| Time per Bit | 243 microseconds/bit | 519 microseconds/bit |
| Load | x 17 Mb/day | x 12 Mb/day |
| Handling Time | = 69 minutes/day | = 104 minutes/day |

**Table 22. Handling Times (Fiscal Year 1995)**

[3] Differences in message handling procedures helped account for the significant difference between transmission and reception times.

## D. CHANGES IN DAILY TRAFFIC LOAD

The daily traffic load increased dramatically in 1995. Users exchanged more messages and put more data in those messages. In the first two quarters, the network handled an average of 12 Mb per day. In the third quarter, the daily average (for the year to date) rose to 19 Mb. In the fourth quarter, the daily average (for the year to date) jumped to 29 Mb. This pattern of increases was driven by a 183% rise in the transmitted load and a 100% rise in the received load. These figures are based on Table 23.

| FY95 Average | Transmitted Load | Received Load | Total Load |
|---|---|---|---|
| **End of 1st Quarter** | 6 Mb/day | 6 Mb/day | 12 Mb/day |
| **End of 2nd Quarter** | 6 Mb/day | 6 Mb/day | 12 Mb/day |
| **End of 3rd Quarter** | 12 Mb/day | 7 Mb/day | 19 Mb/day |
| **End of 4th Quarter** | 17 Mb/day | 12 Mb/day | 29 Mb/day |

**Table 23. Changes in Daily Traffic Load (Fiscal Year 1995 – Moving Average)**

If the rates of increase remain steady over the next five years, the network will face the prospect of handling nearly 3.5 gigabits (Gb) per day by the end of Fiscal Year 2000. This forecast is based on Table 24.

| Year | Transmitted Load | Received Load | Total Load |
|---|---|---|---|
| **1995** | 17 Mb/day | 12 Mb/day | 29 Mb/day |
| **1996** | 48 Mb/day | 24 Mb/day | 72 Mb/day |
| **1997** | 136 Mb/day | 48 Mb/day | 184 Mb/day |
| **1998** | 385 Mb/day | 96 Mb/day | 481 Mb/day |
| **1999** | 1090 Mb/day | 192 Mb/day | 1282 Mb/day |
| **2000** | 3084 Mb/day | 384 Mb/day | 3468 Mb/day |

**Table 24. Forecasted Changes in Daily Traffic Load**

## D. CHANGES IN HANDLING TIME

Handling time also increased dramatically during the course of Fiscal Year 1995. New equipment (*e.g.*, faster modems) led to a reduction in the per-bit handling times, but these reductions did not compensate for the increase in traffic loading. In the first quarter, the network spent 98 minutes handling the daily load. By the end of the fourth quarter, the network spent 173 minutes accomplishing this task. This 77% increase was driven by the rapid growth in message quantity and size. It occurred despite the 20% decrease in per-bit transmission time and the 23% decrease in per-bit reception time. These figures are based on Tables 25 through 27.

| FY95 Average | Time per XMTD Bit | Daily XMTD Load | Time Required to Handle XMTD Load |
|---|---|---|---|
| **End of 1st Quarter** | 302 microsecs/bit | 6 Mb/day | 30 minutes/day |
| **End of 2nd Quarter** | 318 microsecs/bit | 6 Mb/day | 32 minutes/day |
| **End of 3rd Quarter** | 262 microsecs/bit | 12 Mb/day | 52 minutes/day |
| **End of 4th Quarter** | 243 microsecs/bit | 17 Mb/day | 69 minutes/day |

**Table 25. Changes in Transmission Times (Fiscal Year 1995 – Moving Average)**

| FY95 Average | Time per RCVD bit | Daily RCVD Load | Time Required to Handle RCVD Load |
|---|---|---|---|
| **End of 1st Quarter** | 678 microseconds/bit | 6 Mb/day | 68 minutes/day |
| **End of 2nd Quarter** | 746 microseconds/bit | 6 Mb/day | 75 minutes/day |
| **End of 3rd Quarter** | 718 microseconds/bit | 7 Mb/day | 84 minutes/day |
| **End of 4th Quarter** | 519 microseconds/bit | 12 Mb/day | 104 minutes/day |

**Table 26. Changes in Reception Times (Fiscal Year 1995 – Moving Average)**

| FY95 Average | Time Required to Handle XMTD Load | Time Required to Handle RCVD Load | Time Required to Handle Total Load |
|---|---|---|---|
| **End of 1st Quarter** | 30 minutes/day | 68 minutes/day | 98 minutes/day |
| **End of 2nd Quarter** | 32 minutes/day | 75 minutes/day | 107 minutes/day |
| **End of 3rd Quarter** | 52 minutes/day | 84 minutes/day | 136 minutes/day |
| **End of 4th Quarter** | 69 minutes/day | 104 minutes/day | 173 minutes/day |

**Table 27. Changes in Total Handling Times (Fiscal Year 1995 – Moving Average)**

If the rate of increase remains steady over the next five years, the network will not be able to support the demands of its users. By the end of 1997, it will spend the entire 10 hours transmitting and receiving one day's traffic. By the end of 1998, its capacity will be exceeded. The network will not be able to handle one day's load before facing the next day's. This grim forecast is based on Tables 28 through 30.

| Year | Time per XMTD Bit | Daily XMTD Load | Time Required to Handle XMTD Load |
|---|---|---|---|
| 1995 | 243 microseconds/bit | 17 Mb/day | 69 minutes/day |
| 1996 | 195 microseconds/bit | 48 Mb/day | 156 minutes/day |
| 1997 | 156 microseconds/bit | 136 Mb/day | 354 minutes/day |
| 1998 | 125 microseconds/bit | 385 Mb/day | 802 minutes/day |
| 1999 | 100 microseconds/bit | 1090 Mb/day | 1817 minutes/day |
| 2000 | 80 microseconds/bit | 3084 Mb/day | 4112 minutes/day |

**Table 28. Forecasted Changes in Transmission Times**

| Year | Time per RCVD bit | Daily RCVD Load | Time Required to Handle RCVD Load |
|---|---|---|---|
| 1995 | 519 microseconds/bit | 12 Mb/day | 104 minutes/day |
| 1996 | 400 microseconds/bit | 24 Mb/day | 160 minutes/day |
| 1997 | 308 microseconds/bit | 48 Mb/day | 246 minutes/day |
| 1998 | 237 microseconds/bit | 96 Mb/day | 380 minutes/day |
| 1999 | 182 microseconds/bit | 192 Mb/day | 582 minutes/day |
| 2000 | 140 microseconds/bit | 384 Mb/day | 896 minutes/day |

**Table 29. Forecasted Changes in Reception Times**

| Year | Time Required to Handle XMTD Load | Time Required to Handle RCVD Load | Time Required to Handle Total Load |
|---|---|---|---|
| 1995 | 69 minutes/day | 104 minutes/day | 3 hours/day |
| 1996 | 156 minutes/day | 160 minutes/day | 5 hours/day |
| 1997 | 354 minutes/day | 246 minutes/day | 10 hours/day |
| 1998 | 802 minutes/day | 380 minutes/day | 20 hours/day |
| 1999 | 1817 minutes/day | 582 minutes/day | **40 hours/day** |
| 2000 | 4112 minutes/day | 896 minutes/day | **84 hours/day** |

**Table 30. Forecasted Changes in Total Handling Times**

## E. CONCLUSIONS

Our study of the *cc:Mail* performance statistics allowed us to draw the following conclusions:

1. During the average workday, CWD exchanges 29 Mb of message data with the Saint Louis hub. The *cc:Mail* network can handle this entire load in less than three hours.

2. Over the next five years, CWD may see a dramatic increase in the demand for messaging services. At the current rates of growth, the department will face a 3432 Mb average daily load before the end of the year 2000.

3. Unfortunately, the *cc:Mail* network is not improving at a rate that will guarantee its ability to meet the demand for services after 1998. Therefore, it must undergo revolutionary changes[4] within the next two years.

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[4] For example, the network could shift from its 28.8 kbps, dial-up configuration to a 56 kbps or higher, TCP/IP configuration. As another example, the department could procure another server and modem pool and then use these components to establish a second connection to the Saint Louis hub.

# APPENDIX C. COSTS

## A. INTRODUCTION

We used *4G53 Branch's Fiscal Year 1996 Budget* as a means for examining the costs associated with operating and maintaining the LAN.[1]

When we examined the costs, we looked at four budget categories: (1) people, (2) equipment, (3) maintenance, and (4) materials. Civilian salaries, benefits, overtime payments, and travel costs were included in the *people* category. Hardware, software, and telecommunications procurement expenses were placed in the *equipment* category. The *maintenance* category reflected the costs associated with hardware and software maintenance contracts. Finally, the costs of buying paper, floppy disks, and other consumable items formed the *materials* category.

## B. COSTS

*People* is the most significant cost category. During Fiscal Year 1996, 4G53 intends to spend $556,000 on salary, benefits, overtime, and travel. For this total, 4G53 expects to receive 5.4 man-years of effort from a support staff of eight employees.

Another important category is *ADP*. During Fiscal Year 1996, 4G53 intends to spend $210,000 on hardware, software, and telecommunications. This total includes $200,000 for department-wide upgrades. It also includes $10,000 for branch-specific procurements.

*Maintenance* and *materials* are relatively unimportant cost categories. During Fiscal Year 1996, 4G53 intends to spend $40,000 on hardware and software maintenance contracts and $15,000 on consumable supplies.

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[1] CWD does not have to pay for the services supplied by the external networks. All of its information technology costs are absorbed by the LAN.

Table 31 depicts the costs associated with each category. As shown in this table, the branch intends to spend a total of $821,000 operating and maintaining the LAN. 68% of this total is dedicated to *people*, and 25% is dedicated to *ADP*. The remaining 7% is split between *maintenance* and *materials.*

| Category | Budgeted Costs | Percentage of Total |
|---|---|---|
| People | $556,000 | 68% |
| ADP | $210,000 | 25% |
| Maintenance and Materials | $55,000 | 7% |
| **Total** | **$821,000** | **100%** |

**Table 31. FY96 Cost Breakdown**

## C. EVALUATING THE COSTS

In return for the $821,000 it spends on the LAN, CWD receives support for 130 user nodes. By examining the budget in these terms, one can conclude that the department operates its LAN at an annual cost of $6000 per node. This is well below the $8000 to $18,000 "rule of thumb" for estimating networking costs on a per-computer basis [Ref. 11].

## D. CONCLUSIONS

Our study of the budget allowed us to draw the following conclusions:

1. In 1996, CWD expects to spend $821,000 operating and maintaining its LAN. The largest contributors to that budget are people (68%) and automated data processing (25%). The other contributors are maintenance and materials.

2. The $821,000 equates to $6000 per user node. This is well below the "rule of thumb" for network cost estimation. Therefore, we can conclude that the LAN costs less per user node than the industry average.

# APPENDIX D. ETHERNET

## A. INTRODUCTION

There are two basic technologies for upgrading from 10 to 100 Mbps Ethernet, 100BaseT and 100VG-AnyLan. Both have been loosely referred to as "Fast Ethernet," although only the former is the official Fast Ethernet standard. Both have staunch supporters in the telecommunications industry who create almost a polarized environment where Ethernet is concerned. [Ref. 53]

The other method of getting the most out of your Ethernet LAN is to use switching technology. As we will discuss, this is one performance upgrade technology that may not be as great a risk for network managers. This is because Switched Ethernet requires minimal equipment changes to already existing Ethernet LANs, is flexible and incrementally expandable, and generally less expensive than other high performance upgrades.

## B. BACKGROUND

During the development of the original Ethernet standards, fast data rates required technology that revolved largely around coaxial cables. The desire to be able to maintain data networks over the less expensive telephone cable led to the rise of the IEEE's 802.3 10BaseT Ethernet specification. [Ref. 53] This technology has been very popular in a multitude of different organizations because of its simplicity, reliability, and low cost.

The 10BaseT specification calls for two pairs of Category 3 or higher unshielded twisted pair, UTP, wires. The hub is responsible for monitoring the quality of the connection between the hub and the network card, and is capable of shutting off a "bad" connection. The most common configuration for 10BaseT is a sheath of Category 3 UTP. This type of a cable contains four pairs of wires, which is two more than necessary. Because of this, many sites may not have installed or connected all four wire pairs. As

will be discussed later, this may pose problems for sites desiring to upgrade to 100 Mbps Ethernet technologies.

The CSMA/CD media access control protocol allows nodes on the network to access its services. It is a non-deterministic method of media access as opposed to token ring where nodes are granted access to the token for accessing the network in a deterministic fashion. All nodes connected on a logical Ethernet, or connected to the same LAN segment, are in a collision domain. The CSMA/CD structure works well for its LAN segment until the network becomes saturated with nodes desiring access. The use of bridges or routers to segment a network comprising many collision domains may help reduce LAN segment saturation.

## C. "FAST ETHERNET"

Both 100BaseT and 100VG-AnyLAN are performance upgrade technologies capable of supporting traditional Ethernet frames. There are, however, major differences between the two. It is essential for network managers to understand these differences before making a choice on the appropriate upgrade path for their specific networking environment.

### 1. 100BaseT

The official Fast Ethernet standard, 100BaseT provides organizations with one avenue for upgrading to 100 Mbps LANs. Examining its features, advantages, and disadvantages will help network administrators determine if this avenue is appropriate for their network environment.

#### *a. Features*

This version of 100 Mbps Ethernet is more similar to traditional 10 Mbps Ethernet in that it uses the same IEEE 802.3 standard and the same media access control, MAC, layer protocol, CSMA/CD. Many believe this to be the only “pure” form of 100 Mbps Ethernet. [Ref. 53]

Three physical layer specifications within the 100BaseT standard allow it to support a variety of media types. 100BaseTX supports two-pair Category 5 UTP and Type 1 shielded twisted pair, STP. 100BaseFX supports fiber optic cable. Finally, 100BaseT4 covers four-pair Category 3, 4, or 5 UTP. [Ref. 54] Cabling distances are shorter for 100BaseT than they are for 10BaseT because of the higher data transmission speeds. 100BaseT allows up to 100 meters between a network node and a hub and 5 meters between two hubs. Two hubs are allowed between any two network nodes, thus allowing the maximum network to span up to 205 meters. [Ref. 55] This may mean the additional purchase of bridges or routers to upgrade 10BaseT segments that are more geographically dispersed.

#### *b. Advantages and Disadvantages*

Because 100BaseT uses the same CSMA/CD MAC protocol as 10BaseT, users are able to draw from experiences learned on their already installed Ethernet LANs as well as maintain use of some existing network tools. [Ref. 55] Also, the cost of this upgrade technology should be relatively low due to its similarity to 10BaseT. Products are available on the market that are approximately one and a half times the price of standard 10BaseT products. [Ref. 55]

100BaseT enjoys very strong industry support. The Fast Ethernet Alliance includes close to 75% of Ethernet LAN equipment providers with such names as: Bay Networks, Cabletron, Chipcom, Digital Equipment Corp., Grand Junction Intel, National Semiconductor, SMC, Sun Microsystems, and 3Com. [Ref. 54] These members are

striving to assure interoperability of Fast Ethernet products as demonstrated by their informal interoperability tests to ensure compatibility among member companies' products begun in 1994. [Ref. 54]

One of 100BaseT's advantages can also be its greatest disadvantage. This refers to the support of various media types. Because 10BaseT operates on two pairs of Category 3 UTP, many organizations are only wired to support those minimum requirements. While it is true that 100BaseT can operate on Category 3 UTP wire, it requires four pairs. Organizations may not even know their wiring configurations. If the pairs are available, they may not know if they are connected. This problem may require considerable resources to reinstall cable that will support 100BaseT. [Ref. 55]

Organizations may also face costly recabling expenses due to the distance limitations of 100BaseT. Existing 10BaseT networks allow for a much more distributed layout than does 100BaseT. Upgrading may require the purchase of more hardware, such as, bridges and routers to support geographically disperse LANs. [Ref. 55]

One disadvantage of either form of 100 Mbps Ethernet technology is the confusion that exists between the two. Both products have at one time used the name "Fast Ethernet," which leads uninformed buyers to believe these products are the same or at least interoperable.

### 2. 100VG-AnyLAN

Like 100BaseT, 100VG is intended to be a 100 Mbps extension to 10BaseT, and therefore supports IEEE 802.3 Ethernet frame types. Unlike 100BaseT, 100VG is also capable of supporting IEEE 802.5 token ring data frames. This combined support characteristic has led to the "AnyLAN" name. [Ref. 55]

#### a. Features

As mentioned, 100VG supports both the traditional Ethernet and token ring standards. The standard governing 100VG is IEEE 802.12. [Ref. 56] Many would argue that 100VG is not Ethernet, because it does not use the CSMA/CD MAC protocol. Instead, it uses an access scheme called Demand Priority to determine the order in which nodes share the network. [Ref. 55] This is a deterministic network access method designed to eliminate collisions and collision domains. The hub queries each node to see if it needs to transmit any data, therefore, eliminating the need for multiple access.

Demand Priority also provides the capability to prioritize network traffic. Traffic is either high or normal priority. During each "round," the protocol services traffic with a high priority before that with a normal priority. This provides time-critical network applications more immediate access to the network. All nodes requesting access to the network are serviced during each round, however. [Ref. 55] This deterministic network access and high prioritization of traffic leads adherents of 100VG to claim it is better suited to multimedia than 100BaseT. [Ref. 57]

100VG also supports a variety of media types. It offers four-pair operation over Category 3, 4, or 5 UTP, two-pair operation over Type 1 STP cable, and support for fiber optic cabling. Cabling distance limitations are dependent upon the type of installed cabling. For Category 3 UTP and Type 1 STP, node-to-node or node-to-hub distances are 100 meters. For Category 5 UTP, distances are 200 meters, and for fiber optic cable, distances are 2,000 meters. Hubs can be cascaded three deep, with the maximum distance of 100 meters for Category 3 UTP and 150 meters for Category 5 UTP [Ref. 55].

#### b. Advantages and Disadvantages

Because 100VG supports both Ethernet and token ring frame formats, it provides a high-speed upgrade path for both types of networks. This becomes important

for larger organizations trying to create an enterprise network, thus requiring them to interconnect many diverse types of LAN segments. 100VG is also finding its niche in organizations dependent upon real-time multimedia. Its deterministic operation, as opposed to the non-deterministic operation of 100BaseT, is what allows for greater support of this type of data. The Demand Priority scheme combined with prioritization provide guaranteed network access, enabling network performance to be predicted, regardless of load. [Ref. 55]

This form of 100 Mbps Ethernet upgrade may be preferable for some organizations due to the limited cabling capabilities of 100BaseT. Because 100VG requires four-wire pairs over Category 3, 4, or 5 UTP, many organizations may still be required to recable.

While 100VG does not have as great a share in the market, it does maintain strong support from a few industry leaders, to include: Hewlett-Packard, IBM, AT&T, Morotola, Thomas-Conrad, and Plaintree Systems. This reduced market share along with the greater costs for the smart hubs required by this technology indicate that the already higher costs for 100VG are not likely to drop as quickly as those for 100BaseT. [Ref. 56]

Network administrators need to understand the differences between these forms of 100 Mbps Ethernet in order to best support upgrade paths for their organization's networks. They should understand the advantages and disadvantages of 100BaseT, 100VG, and the next topic, Switched Ethernet.

## D. SWITCHED ETHERNET

### 1. Faster Shared Media Not Necessarily the Solution

Ethernet uses shared medium access to transport data. Simply installing a faster shared LAN medium may or may not solve network performance problems [Ref. 29]. This is because Ethernet uses CSMA/CD. The greater number of users desiring access to the network will increase the number of collisions. As collisions increase, there will

come a point where the network will effectively cease to function because too many collisions are occurring.

In smaller networks, increasing network speed will show an increase in network performance, because users are able to send their data faster, thus reducing the time that the media is being used. As the network grows, however, the same problem of too many collisions will again occur. That is why in larger networks the need is for greater bandwidth (carrying capacity) and not necessarily greater speed [Ref. 29].

The expense of installing LAN media operating at 100 Mbps to every desktop of a larger network is another major consideration when upgrading network capacity. It is an expense that is usually not necessary for every user in networks where various types of personnel and applications are being supported.

The network manager wants to be able to provide higher speeds (100 Mbps) to those "power users" and the file and application servers, while offering lower speeds (10 Mbps) to normal users. At the same time, he or she must be able to provide acceptable network performance by efficiently using the available bandwidth. He must also meet these requirements in the most cost-effective manner.

### 2. What is Ethernet Switching?

A LAN switch operates generally the same way that a telephone switch does. It reduces media sharing by containing traffic to the segments of the media for which it is destined and not transmitting over all segments of the media. "Switching establishes a direct line of communication between two ports and maintains multiple simultaneous links between various ports" [Ref. 58]. Switching does not increase the amount of bandwidth available on the network, but uses it considerably more effectively.

#### *a. Frame Switching*

Frame switching was the first Ethernet switching technology, introduced in 1990. In this type of Ethernet switching, each workstation (or node) connects directly to one port on the switch. The workstation may transmit anytime it is ready, because the switch will eliminate collisions. The switch port is responsible for receiving the data frame and sending it to the appropriate destination. Therefore, each port of the frame switch must integrate MAC layer functionality in order to extract the destination address of the incoming frame [Ref. 59].

There are basically two techniques for transmission in frame switching, cut-through switching and store-and-forward switching. Cut through switching will begin to send packets to their destination as soon as the address has been read (within the first 20-30 bytes of the frame). While this reduces transmission latency, it can result in the transmission of an error-laden frame [Ref. 29, 58]. Store-and-forward switching buffers incoming packets in memory until they are fully received, checked for errors, and the destination address is extracted in order to forward the packet. This technique increases the processing time but helps to eliminate bad packets and collisions that can adversely effect the overall performance of the segment [Ref. 29, 58]. Some switches may even use a combination of these techniques. They begin with cut-through switching, and through cyclic redundancy checks (CRCs) they can monitor the number of errors. When that number of errors reaches a certain point, the switch transfers to store-and-forward switching until the number of errors declines. This is called threshold or adaptive switching [Ref. 58].

#### *b. Segment Switching*

Rather than eliminating the shared media scheme of connecting nodes, segment switching breaks the overall network into smaller segments to attempt to reduce collisions. Within each segment the shared media and CSMA/CD properties still apply.

Under ideal circumstances the system administrator defines the segments so that most of the traffic on each segment remains local to that segment and collisions are not a considerable problem [Ref. 59].

#### c. *RISCs and ASICs*

The type of CPU installed in a switch will also play a role in the architecture of the switched network. Reduced Instruction Set Computer, RISC, processors are typically used for general purpose applications. While they are not well suited to perform specific operations and are typically a store-and-forward (slower) switch, they do have certain advantages. RISCs are relatively inexpensive compared to other alternatives. Switches with this type of CPU can forward frames according to data link layer address information, and can make forwarding decisions based on network layer address information. Upgrading RISCs can be accomplished easily with software downloads [Ref. 58].

The other type of processor is an Application Specific Integrated Circuit, ASIC. They are custom designed to handle specific operations and are "cast" in hardware. This typically means they are more expensive and any changes required means changing the hardware. They typically perform cut-through forwarding of frames based on MAC destination addresses [Ref. 58].

### 3. Ethernet Repeaters, Bridges, and Routers

Various other types of networking devices can perform some of the same functions of an Ethernet switch. Network Administrators need to understand the differences among these various products to determine the equipment most appropriate for their system. These products include Ethernet repeaters, bridges, and routers. The performance of these products and switches can be characterized according to port-to-port forwarding bandwidth, total forwarding bandwidth, and latency.

Port-to-port forwarding bandwidth indicates the device's capability to deliver packets at "wire speed." This is important because it indicates when the device is operating as efficiently as the Ethernet wire, which moves data at 14,880 packets per second (PPS) at 10 Mbps. This would mean the device is delivering at maximum throughput rates [Ref. 60]. Total forwarding bandwidth is the maximum rate at which packets move through the system and are received by all destination ports. Latency, discussed earlier, is the time delay through the device. It is commonly measured from the first bit of information received [Ref. 60].

The primary purpose of a repeater is to recondition the electrical signal being transferred in order to extend the distance that packets can be sent. This allows users in an organization to transmit further distances, and thus extend their range to include more users, applications, files, and other network services. A repeater does not have any filtering capabilities. It forwards all received packets to the rest of the network, regardless of the packet's destination address. Important performance characteristics of repeaters include very low latency, protocol independence, and in some situations a security risk due to the fact that all nodes see all traffic passed by a router [Ref. 60].

A bridge differs from a repeater in that it forwards packets only when necessary, based on the packet's destination address. Bridges do not forward collisions or errors because they use the store-and-forward technique, which exhibits high latency as compared to the cut-through technique. It would also not be uncommon for a bridge to exhibit internal blocking, a condition where the device's maximum forwarding capacity, expressed in Mbps, is less than the sum of the data rates across all port pairs [Ref. 60].

Routers also forward packets only to their appropriate destination, however, this is based on protocol information embedded in the packet rather than the destination address. Routers, therefore, are protocol dependent. Other characteristics of routers include that they do not propagate collisions or errors, they can support wire speed data rates, and they have high total forwarding bandwidth. It is also not uncommon for routers to exhibit internal blocking. The router modifies the contents of all forwarded

packets, unlike repeaters, bridges, or switches [Ref. 60]. The characteristics of the various Ethernet devices are summarized in Table 32 [Ref. 60].

| Characteristic | Repeater | Switch | Bridge | Router |
|---|---|---|---|---|
| Price per port | $75-200 | $200-2,000 | $1,000-3,000 | $1,000-5,000 |
| Port-port forwarding bandwidth | Always wire speed | Wire speed possible | Wire speed possible | Wire speed possible |
| Total forwarding bandwidth | 10 Mbps | High | High | High |
| Latency | <3 microseconds | <40 microseconds | 50-1,500 microseconds | 50-1,500+ microseconds |
| Forwarding decision based on Ethernet address | No | Yes | Yes | No |
| Protocol independent | Yes | Yes | Yes | No |
| Modifies forwarded packet | No | No | No | Yes |
| IEEE Standards | IEEE 802.3 | | IEEE 802.3 | |

**Table 32. Ethernet Device Characteristics From Ref. [60].**

In addition to the performance characteristics of switches just described, Switched Ethernet has other advantages over the traditional repeated, bridged, and routed Ethernet. Switched Ethernet allows microsegmentation of an organization's overall system, which will allow you to connect segments operating at differing line speeds (i.e. 10 or 100 Mbps). It also allows you to change a 10 or 100 Mbps segment of shared media to 10 or 100 Mbps of dedicated bandwidth. Either LAN segments or individual "power users" can be connected to a port on a switch, without having to modify any software or hardware already running. The cost effectiveness, simplicity, and flexibility through switching cannot be matched by a bridge/router configuration [Ref. 58].

### 4. Advantages of Switched Ethernet

Other advantages of Switched Ethernet make it an attractive alternative to Network Administrators. Some of the basic advantages include: increased system performance, reduced collisions, low incremental deployment costs, improved security, and low and predictable network response time [Ref. 60].

#### *a. Building on Existing Ethernet Networks*

Many organizations have already invested resources in establishing Ethernet LANs. They would like to see that investment grow with the organization's needs rather than establishing new LANs based on entirely new technologies requiring *vast* amounts of resources. Switched Ethernet has the capability to do just that. It is flexible in that it is incrementally expandable. Network administrators can improve the performance of the LAN for those users or segments who require it and maintain the system for those users not currently requiring increased speeds or bandwidth. This type of switching is simple in that it can be implemented by procedures entirely in hardware, thus software is not required for data movement [Ref. 29].

#### *b. Full-Duplex Concepts*

For point to point links, such as between servers or between a switch and a server, a line operating in full-duplex mode can offer substantial increases in performance. Full-duplex means that traffic can flow in both directions at the same time. Standard Ethernet operates in half-duplex, or traffic moving in only one direction at a time, mode [Ref. 29]. The two key concerns with trying to use full-duplex operation to your advantage are that it only works on point to point links and that increased performance will only be recognized where the traffic loads between these two links is symmetric [Ref. 61]. This concept has the potential to double the bandwidth operation

and to eliminate collisions, because it simultaneously uses one pair of wires for transmission and another pair for reception. It would be best used in situations where two servers or two switches are connected. There could also be improvement for connection between a file server and a switch where even though most traffic travels in one direction, substantial traffic flows in the other direction [Ref. 29].

#### c. *Future Technology and Upgrading Switched Ethernet Networks*

One final advantage of great importance for organizations expecting growth or desiring to achieve the "enterprise network" in the future is that Switched Ethernet is a stepping stone to the anticipated networking technologies of the future, such as ATM. Organizations will be able to adopt ATM as a backbone technology with Ethernet networks being the interface between the desktop and the backbone [Ref. 29]. This proves a much less risky network architecture than jumping ahead to install ATM networks throughout an organization.

### 5. Criteria for Selecting a Switch

The following helpful reminders are provided when selecting a switch for performance in a LAN [Ref. 58]:

1. Get a switch that does not drop frames.
2. Be concerned, but not too concerned with latency.
3. The application will determine the need for cut-through or store-and-foreword techniques.
4. Multimedia stations need dedicated switched ports.

5. It is best to keep a 1:1 ratio between demand (stations) and resources (servers), or increase the number of lines to the server.

6. Determine the number of bad frames that exist on the network prior to installing any switches.

## E. CONCLUSIONS

Migrating to 100 Mbps Ethernet support for an organization's networks is possible through various different avenues. 100BaseT, 100VG, and Switched Ethernet provide three different approaches. Which is best for an organization depends upon its specific requirements. 100BaseT is a prime candidate for an organization that currently supports 10BaseT with Category 3, 4, or 5 UTP wiring (provided wiring provides four-pairs) and whose network nodes are not geographically disperse. The organization will be able to upgrade with minimal cost while retaining the resident knowledge gained from the existing 10BaseT networks.

100VG provides a good upgrade path for an organization desiring to create an enterprise network from both Ethernet and token ring LAN segments. The nodes on an individual segment may be more geographically disperse than that allowed by 100BaseT networks, and it also requires four-pairs of Category 3, 4, or 5 UTP wire. This technology is also well suited for organizations that must support real-time multimedia , because of its deterministic network access protocol.

Switched Ethernet provides a more flexible means of upgrading existing traditional Ethernet LANs. If not all users require 100 Mbps support, Switched Ethernet can support both 10 Mbps and 100 Mbps segments on the same LAN. It provides a more cost effective means of migrating to higher speeds, and it provides an excellent means of growing into the "super-technologies," such as ATM.

## APPENDIX E. FDDI

### A. INTRODUCTION

Fiber Distributed Data Interface (FDDI) is a set of standards developed by the American National Standards Institute (ANSI) (X3T9.5) for a network architecture designed to operate at very high speeds over fiber optic lines. [Ref. 36] It is a well established set of protocols that have been primarily implemented in backbone networks. It has also been used efficiently as a back-end network to connect such devices as processors to storage devices. As more capabilities are being pushed to the desktop, however, FDDI is providing an excellent option for front-end networks, or what we typically see in a LAN where one or many servers are connected to many workstations. With the direction of networks, as discussed in Chapter VI, Target Environment, moving toward greater bandwidth required to the desktop, FDDI provides an excellent option for new or expanding networks.

### B. CHARACTERISTICS OF FDDI

Many organizations associate FDDI with "huge financial investment" and therefore, do not consider it as an option for their expanding network needs.[1] FDDI, as well as any other high speed and bandwidth network option, does involve costly investments. Because FDDI offers some features that may be critical to an organization, it may prove to be the most cost effective solution for that organization. Therefore, its characteristics should be examined as an option for new and expanding networks.

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[1] For example, the typical cost per port (i.e. concentrator) for FDDI is approximately $2,000 and the typical cost for a client adapter card is approximately $1,000. [Ref. 64]

### 1. Topology

The logical topology off FDDI is a dual counter-rotating ring. This dual ring provides a redundant data path in the event of a cable failure. [Ref. 55] There are various advantages of a ring topology. First, it is easier to isolate faults in a properly wired ring network. Such a network is more extendible to higher speeds than a contention-based bus network. This is because there is a greater risk of collision in a contention network as the bandwidth increases, thus the efficiency decreases as the network bandwidth increases. A ring network is more applicable to longer distances. It also provides better performance at high loads than does a contention-based network. Finally, ring networks are better suited for fiber optic technology and are capable of intermixing different media along the ring. [Ref. 35]

### 2. Media Access Control

FDDI media access is based on a timed token passing access method. It differs from the traditional token access method in that stations on the network measure the time required for the token to walk around the ring in order to determine the usability of the token. [Ref. 35]

In the normal token access method, a token is circulated among the stations in a round-robin fashion. When a station receives the token it is granted access to the network for a fixed interval, called the token holding time (THT). The time between successive arrivals of the token at one station is the token rotation time (TRT). In the media access method used by FDDI, stations agree to limit their transmissions so that the TRT does not exceed a preset target. Because the number of stations is known and the THT is fixed, stations can predict the TRT. This prediction is known as the target token rotation time (TTRT). [Ref. 35]

With asynchronous class traffic, data traffic that is not time critical, stations agree to limit the THT to the difference between the TTRT and the TRT. If the TRT is equal

to or more than the target, however, the token is considered late and that station does not transmit. Synchronous, or time sensitive traffic can be transmitted on any token, early or late. Because synchronous transmissions on a late token may cause the token rotation times to be above the target, the duration of synchronous transmissions is small and preallocated. Also, stations may be assigned different synchronous allocations. The final class of traffic is restricted asynchronous. It is used for a very large burst of data requiring several token rotations. With this method, the transmitting station marks the token as restricted. The token can still be used by stations with synchronous traffic, but it cannot be used for asynchronous traffic. Only the stations involved in the restricted dialog will be allowed to use the token for asynchronous traffic. Upon completion of the dialog, the station that restricted the token will "unrestrict" it. [Ref. 35]

### 3. Transmission Media

FDDI was designed for operation over fiber optic cable. To enhance its capabilities as a workgroup solution, support for STP and UTP has been added to the specification. [Ref. 55] Although fiber is more expensive, it does have several advantages. Fiber has a lower attenuation than copper cables. This means that longer distance communication is possible without needing to regenerate the signal with repeaters. The carrying capacity, bandwidth, of a single fiber is *astronomically* greater than that of a single copper cable. This provides for a higher data rate transfer than copper and means several copper wires may be replaced with only a single fiber cable.

Because fiber optics deals with the transmission of light, there is no electromagnetic radiation as there is with transmission of signals over copper cables. This often causes the side-effect of crosstalk which is not a difficult design issue for fibers. There is also no radio-frequency interference to induce noise because light is not effected by radio frequencies.

Fibers are considered much more secure than copper wires for a couple of reasons. First, electromagnetic waves produced by electric current traveling through a

copper cable make it possible to listen to the electrical signal without touching the cable. Because the transmission of light does not produce such waves, fiber is considered more secure. Second, it is much more difficult to "tap" into a fiber line than it is with a copper wire. Any attempt to do so would be detected fairly easily. Other advantages of fiber include that it is light weight, highly resistive to chemical attack, less sensitive to temperature, more safe from shorting or sparking, and more energy efficient. [Ref. 35]

Choosing the right type of fiber is an important consideration. The major components of a fiber optic cable include the core and the cladding. [Ref. 36] The core consists of the glass or plastic fibers through which the light travels. It's diameter is anywhere from two to several hundred microns. The cladding surrounds the core and is a protective layer with a lower index of refraction than the core. It is the lower index of refraction that redirects the light back on its path through the core. The diameter of the cladding will be anywhere between 100 microns and a millimeter. Other components of the fiber optic cable include the buffer, strength members and jacket. [Ref. 36]

Fiber can be either single-mode or multimode, with "mode" referring to the possible paths for light through the cable. Single-mode fiber has a much narrower core, generally less than 10 microns, therefore light can take only a single path. [Ref. 36] This type of cable has the least signal attenuation, thus allowing signals to travel greater distances. It also offers transmission speeds of 50 Gbps or higher. However, it is the most difficult to install, because it requires precision, and it is the most expensive of the types of fiber. [Ref. 36]

Multimode fiber has a wider core than single-mode, thus providing light more room to follow multiple paths through the cable. There are two types of multimode fiber which are distinguished by how abruptly the index of refraction changes between the core and the cladding. These are known as step index cable and graded index cable. Step index is a cable where the transition from the index of refraction of the core and the index of refraction of the cladding is made in a single step. This type of cable is the cheapest and easiest to manufacture. [Ref. 35] Graded index is a cable where the index of the fiber core decreases as we move radially away from the axis, thus the index

changes gradually. This type of cable is designed to help reduce modal dispersion, which is the distortion of the original signal caused by the different paths the rays of light take when traveling the length of the cable. The rays which travel straight down the center of the core will arrive at the receiver faster than those which are reflected off of the cladding. [Ref. 35]

FDDI can also run on Category 5 UTP. Because the pinout for Twisted Pair-Physical Media Dependent (TP-PMD) is different from that for Ethernet TP-PMD patch cables are required in order to use existing Category 5 UTP for FDDI. [Ref. 62]

### 4. Enhancing Fault Tolerance

To prevent the failure of any one station from bringing the entire network down, designers of FDDI had to implement a number of techniques. A form of optical bypass allows a failed station to be isolated from the remainder of the network. This provides a bypass to station failures, but does nothing when the failure is in the cable. This is the reason for using a dual ring. The second wire is considered to be the back-up for failures to the first. There is also a technique for reconfiguration, known as *wrapping*. This allows two stations on either side of a completely severed cable to reconfigure their internal paths such that the faulted wire is no longer used. [Ref. 35] In short, it redesigns the ring.

Finally, the technique of creating a star shaped ring by using a concentrator is employed in FDDI for fault detection and isolation. All stations on a segment of the network are wired to the concentrator which is able to continuously monitor the status of its stations. As a failure occurs, the concentrator is able to detect and isolate the stations or cables found inoperable. [Ref. 35]

## C. ADVANTAGES AND DISADVANTAGES OF FDDI

The already mentioned techniques for enhancing fault tolerance in FDDI make it a highly available and reliable network option. Its token based access method provides deterministic performance. [Ref. 55] These features combine to make FDDI an outstanding option for organizations that require real-time communications for critical data, such as medical consulting. They also make FDDI a prime candidate for backbone networks.

FDDI allows a larger network diameter than other 100 Mbps networking options. It allows a maximum network length of 200 kilometers and provides for up to 500 stations on a single ring. [Ref. 54] These stations can be either *dual attached*, meaning attached to both counter rotating rings, or *single attached*, meaning attached to the primary ring only. Dual attached stations are usually hubs or server adapters, but can be important workstations. Single attached nodes are often based on UTP cable and allow connection to an FDDI concentrator. [Ref. 55]

FDDI has exceptional performance at high loads compared to 100BaseT Fast Ethernet and 100VG-AnyLAN. [Ref. 63] It supports multimedia applications well due to its deterministic operation and bandwidth allocation mechanisms. [Ref. 62] Additionally, it provides greater security than other options.

The primary disadvantage of FDDI is that it is a degree of magnitude more expensive than other high-speed options. Hubs average about $1,500 per port and network adapters for the desktop average slightly more than $1,000. [Ref. 62] That is in addition to the costs of installing fiber optic cable, which will vary considerable depending upon the organization's layout and the type of cable to be installed. There are also considerable costs involved in training staff members to install and work with fiber optic cable. [Ref. 62] The costs of FDDI are not coming down as quickly as other technologies. This leads some to believe that other high-speed technologies, such as ATM, will surpass it. [Ref. 55]

Other disadvantages of FDDI include that it is considered difficult to install. "The initialization scheme required for stations to enter the ring may cause some headaches during configuration, but once the FDDI network is up and running, it is a solid, stable protocol that needs very little maintenance." [Ref. 62] Finally, FDDI to the desktop is considered by some to have too much overhead to make it cost-effective. Because not all organizations require voice, video, and other more dynamic forms of data, FDDI is often not required to the desktop. It may be more appropriately used in backbone networks or server clusters. [Ref. 62]

## D. CONCLUSIONS

FDDI is a highly efficient and reliable technology for high speed data networks. Because it is an order of magnitude more expensive than other options, many organizations do not wish to consider running it to the desktop. It has, however, found a niche in organizations that require its reliable characteristics for backbone support or for other critical connections. To summarize, installing FDDI makes sense when organization require the following: [Ref. 35]

1. High bandwidth
2. Large interstation distance
3. Large network periphery
4. Large number of nodes
5. Access time guarantee
6. Throughput guarantee
7. High availability
8. High reliability
9. High security
10. Noise immunity.

# APPENDIX F. ATM

## A. INTRODUCTION

The explosion in telecommunication capabilities we are currently experiencing requires that systems be able do more in much less time than ever before. Various trends in the computer and communications industries facilitate the typical user's desire to want more of these capabilities at his or her fingertips. For example, high bandwidth applications, such as, CAD/CAM and interactive multimedia are becoming more common in all types of organizations than ever before. More and more users are demanding access to these types of applications on their local LAN segments. The number of users on a typical LAN segment is increasing, and there is also extensive internetworking between local and remote LAN segments. These are various examples of reasons why the current networks are being stressed to their limits if not already having exceeded them. To keep pace with users' demands, organizations need a networking technology that is *fast*, has a *high bandwidth*, and is *flexible* to its changing needs. ATM is perhaps the best prospect to meet all of these needs. Currently seen as a wide are networking technology, ATM also offers solutions to local networking needs.

## B. WHAT IS ATM?

ATM is a developing packet-switched, broadband network architecture that is designed to combine the high efficiency of packet switching (good for data networks) with the guaranteed bandwidth of circuit switching (good for voice/telephone networks) [Ref. 28]. This is done by packaging information in small, fixed-length packets called cells, therefore ATM is a form of cell relay to distinguish it from frame relay. Each cell is 53 bytes long, with 48 bytes of data and 5 bytes of header information, or overhead. Cell relay is able to keep the cell size small because it depends on the high reliability of the transmission media used today.

One of the primary advantages of ATM is that it is a scaleable technology in both speed and geographic scope. ATM can operate at slow speeds, 1.544 Mbps or less, to the very fast speeds, 2.4 Gbps or more. The high bandwidth and ability to transmit multiple types of data make ATM an attractive architecture for networks ranging from LANs to MANs to WANs. This feature makes ATM particularly attractive for enterprise networks, because they combine all levels of networking. Some of ATM's critical features include [Ref. 36]:

1. Transmission over fiber optic lines
2. Capability for parallel transmissions
3. Operation at maximum speed at all times
4. Use of fixed-length cells
5. Error correction and routing in hardware
6. Transmission of voice, video, and data at the same time
7. Easier load balancing.

## C. THE NEED FOR ATM

### 1. High Bandwidth Requirements Driving ATM Needs

Some of the current trends in computing are making a wide range of new applications available to the desktop. What once required the high end capabilities of mini and mainframe computers can now be accomplished on the personal computer. First, there is the tremendous improvement in performance of processor chips, which is nearly doubling every year [Ref. 31]. Also showing improvement are computer peripherals, such as disk systems allowing larger amounts of data to be stored and transferred to the desktop. These computing resources are becoming capable of handling gigabits of data, resulting in greater user access to high end applications that require exceptional computing power or bandwidth.

Another trend that is taxing the capabilities of current networks is the increasing use of dynamic data, such as audio and video. To support this type of data, networks must provide continuous, uninterrupted data transfer in a predictable manner. These types of data often create a traffic load higher than traditional shared-bandwidth, connectionless networks can handle without interruptions [Ref. 28].

People are conducting business via fax and email instead of with a telephone call or a letter as in the past. This shift of delivery methods results in a radical increase in data traffic. Also, mobile computing requirements are changing. People are demanding access to the same capabilities they have at their office. "In short, today's businesspeople need a universally accessible network that can handle large files promptly and that can transmit text, graphics, audio, and video with equal ease" [Ref. 28].

The concept of "enterprise networking" is a growing trend in computing that relies on "internetworking." Internetworking can be defined as a network that is composed of two or more smaller networks that can communicate with each other via some type of communications path [Ref. 36]. This could consist of various types of connections, such as LAN to LAN, LAN to mainframe, or LAN to WAN. Internetworking is characterized by various factors, such as, enabling LAN segments with disparate networking technologies to connect with one another. This allows each segment to use the technology that best suits its needs without interfering with the connection between the two. It also eases transitions or upgrades from one networking technology to another [Ref. 31].

To sum up the need for a high bandwidth technology, such as ATM, is due to these basic reasons [Ref. 30]:

1. The move towards high bandwidth desktop applications
2. The increased traffic load on local LAN segments
3. The increased internetworking between local and remote LAN segments.

### 2. The Multimedia Environment Driving the Need for ATM

The change in applications required at the desktop has already been described. Interactive multimedia can certainly be considered one of these such tools, but it goes much further than just an application. Multimedia is a much more complex term, one about which authors often disagree. To some it means simply adding a graphic to a text file, but a more accurate definition would include some of the following characteristics [Ref. 28]:

1. Multiple delivery mechanisms, such as, CD-ROMs, LANs, WANs, and wireless networks.
2. Multiple types of content, such as video, audio, graphics, and text
3. Multiple applications, including desktop videoconferencing, collaborative, workgroup programs, video or audio electronic mail, and video or audio enhanced documents,
4. Multiple delivery locations, such as offices, homes, cars, and client sites.

Simply within this definition of multimedia there is a wide range of computing requirements. For example, some multimedia activities, such as reading an email message that has a voice message attached, require *minimal* interaction between the user and the material. Others, such as videoteleconferencing, require a *high* level of two-way communications [Ref. 28].

The following scenario illustrates an example of the need for multimedia in the operation of today's organizations:

> Three engineers in different cities need to collaborate in real time using their desktop systems. They need to see each other, view shared documents, and exchange files during their joint work session. For the network to facilitate this collaboration, it must deliver large amounts of data. Some data transfer occurs in predictable streams (such as video images of each participant) and some comes in bursts (such as a revised CAD file or the results of a decision support query to a host database) [Ref. 28].

As will be illustrated shortly, ATM is the most promising technology to handle the needs for high bandwidth technology and the need to support multimedia. It offers the flexibility to give each computing session its own bandwidth as required rather than jeopardizing continuity and responsiveness by requiring sessions to share bandwidth. At the same time it provides dynamic bandwidth assignments so that network capacity is not wasted on permanent connections between two devices that may communicate infrequently [Ref. 28].

## D. THE DEVELOPMENT OF ATM

ATM is unique in that it is a product of two differing communities, the computing community and the telephone community. The versatility of ATM allows it to support the differing characteristics of each of these two groups. As a result of its duality, the desired standards for ATM of the telephone community have occasionally clashed with the desired standards for ATM of the computing community [Ref. 31].

### 1. The Telephone Background of ATM

There are two basic changes in the telephone industry that have assisted the development of ATM for communications needs. First, telephone networks are increasingly becoming computerized. This is a result of the shift from analog to digital telephone technologies and the increase in service offerings (call waiting, call forwarding, discount dialing plans, etc.). Second, the introduction of high capacity fiber as the communication medium has led to a consolidation of transmission lines. One fiber optic line can replace tens or hundreds of copper wires, resulting in telephone companies multiplexing far more circuits onto the same link and at higher bandwidths. It is important to note, however, that the theoretical capacity of these fiber networks is far more than voice traffic is likely to need [Ref. 31].

### 2. Major Assumptions Behind the Design of ATM

There are four basic assumptions behind the design of ATM which have led to a number of critical architectural principles [Ref. 32]. First, ATM networks will be organized in a hierarchy, with local user equipment connected to regional ATM providers, who are in turn interconnected by national or international ATM providers. This assumption leads to the design principle that the ATM specifications focus on three interfaces of ATM networks. The User-Network Interface, UNI, defines the set of services that will be offered to network subscribers by an ATM network provider. The Network Node Interface, NNI, defines how switches within a local carrier's network will communicate. Finally, the Broadband Intercarrier Interface, BICI, defines the interface between a local exchange carrier and an interexchance carrier's network [Ref. 32].

The second design assumption is that ATM will be a connection-oriented service. This simplifies the channel and path identifiers, which will be discussed later. Third, ATM is expected to be run over fiber optic networks with extremely low error rates. This simplifies the cell structure, reducing the overhead required for each cell. Finally, it is desirable that ATM support very low cost attachments. To accomplish this, the ATM standards bodies chose to prohibit cell reordering, which allows attachments to use simpler forms of buffering [Ref. 31].

## E. HOW DOES ATM WORK?

ATM is a connection-oriented, packet-switched form of cell relay using standard, 53 byte cells. The ATM architecture is organized into layers, similar with other networking technologies, and it is also organized into planes which specify domains of activity.

### 1. ATM Layers

ATM is composed of three layers, the Physical Layer, the ATM Layer, and the ATM Adaptation Layer. The Physical Layer corresponds to the physical layer of the OSI Reference Model. It sends and receives bits on the transmission medium and it sends and receives bits to the next highest layer, the ATM layer. The Physical layer has two sublayers, Physical Medium, PM, and Transmission Convergence, TC. The PM sublayer's functions include the electrical or optical interface into the transmission medium and the timing and recovery of those bits on the transmission medium [Ref. 30]. The TC sublayer has five functions: frame generation, frame adaptation, cell delineation, Header Error Correction, HEC, generation, and cell-rate decoupling. The TC sublayer is responsible for making sure valid cells are being created and transmitted. The ATM Forum, an organization dedicated to defining and implementing ATM, allows for various UNI types of interfaces to include [Ref. 36]:

1. SONET connections at 155.52 Mbps
2. DS3 connections at 44.736 Mbps
3. 100 Mbps connections using 4B/5B encoding, often called Transparent Asynchronous Transmitter/Receiver Interface (TAXI)
4. 155 Mbps connections using 8B/10B encoding.

Other interfaces under development include [Ref. 30]:

1. DS1/E1, STS-1 over unshielded twisted pair category 3 (UTP-3 cable)
2. STS-3c over unshielded twisted pair category 5 (UTP-5 cable)
3. Universal Test and Operations Physical Interface for ATM (UTOPIA) interface.

The ATM layer performs four operations on cells: multiplexing, VPI/VCI translation, header generation, and flow control. Basically, the ATM layer creates the cells and uses the Physical layer to transmit them [Ref. 36].

The ATM Adaptation layer maps the higher layers into the ATM layer. It consists of two sublayers, the Segmentation and Reassembly, SAR, sublayer and the Convergence sublayer, CS. The SAR segments packets received from higher layers into fixed length ATM cells for transmission and does the reverse upon receipt. This sublayer also deals with cells that are out of order or lost.

The CS deals with the different classes of services defined by three parameters: the timing relation between source and destination, the bit rate, and the connection mode. The CS provides the interface for the various services through service access points, SAPs. It is service dependent in that it performs functions required by the AAL type in use [Ref. 4]. The four classes of services are described as follows [Ref. 30]:

1. Class A: connection-oriented, constant bit-rate data with a timing relationship between source and destination. This is appropriate for voice data.
2. Class B: connection-oriented, variable bit-rate data with a timing relationship between source and destination. An example would include video transmissions during teleconferences.
3. Class C: Connection-oriented, variable bit-rate data with no timing relationship between source and destination. This is appropriate for data transmissions.
4. Class D: Connectionless, variable bit-rate data with no timing relationship between source and destination. Examples include SMDS or LAN traffic.

Each class is best suited by an AAL protocol specific to its needs. The protocols are [Ref. 30]:

1. AAL 1: Class A
2. AAL2: Class B

3. AAL 3 / 4: Class C and D
4. AAL 5: Class C and D

AAL 5 was developed by the computing industry to provide a more efficient protocol for data communications than AAL 3 / 4 [Ref. 31].

ATM is also defined by its plane structure. The planes are domains of activity and are known as the control plane, the user plane, and the management plane. The control plane provides call connections to be established and maintained. The user plane is where users or nodes exchange data. The management plane is where network management and layer management services are provided [Ref. 36].

### 2. ATM Interfaces

ATM interfaces, discussed earlier, focus on three areas: the UNI, the NNI, and the BICI. The UNI describes the services that the ATM network provider will offer to the user. There are both public and private UNIs. A public UNI connects a private ATM switch to a public ATM service provider's network, whereas a private UNI connects ATM users with the ATM switch. The NNI defines how switches within a single local exchange carrier's, LEC, network will communicate. Additionally, that LEC is not limited to using a single vendor's switches. Finally, the BICI defines the interface between the LEC and an interexchange carrier's, IXC, network [Ref. 32].

### 3. ATM Connections: VPIs and VCIs

Virtual paths (VPs) and virtual channels (Vcs) are how virtual circuits are defined for the transport of ATM cells. A VC can be described as an individual end-to-end circuit, and a VP is a collection of VC's all having the same end-points. The VP and VC identifiers, VPI and VCI respectively, are defined in the cell header information and are used for cell routing. VPIs and VCIs function similarly to a telephone number with an

area code, analogous to the VPI, and the number itself, analogous to the VCI. The switch will examine an incoming cell, determine if it is "local" or "long-distance" and route based on the VCI for the former and VPI for the latter [Ref. 31].

## F. ADVANTAGES AND DISADVANTAGES OF ATM

### 1. Advantages of ATM

An important advantage of ATM to understand is that it receives unparalleled industry support. The ATM Forum is a perfect example of such support. It is a organization composed of communications and computer vendors desiring to manufacture ATM products or provide ATM services. The organization assists formal standards organizations, such as the ITU-T and ANSI, in developing ATM standards. The ATM Forum defines Implementation Agreements which represent agreements for product and service implementations among the members of the organization and it forwards these agreements to the formal standards bodies to be incorporated into national and international standards [Ref.32].

Another, already mentioned, advantage of ATM is its scalability. Since ATM is based on switching technology, bandwidth is not shared with multiple users. You can add more switches to accommodate increased network demand. ATM is also available at various speeds, allowing a network segment to operate at the speed it requires and not have to pay for unnecessary increases [Ref. 28].

ATM is flexible and dynamic with regards to bandwidth assignment. It is flexible to accommodate various types of payloads, such as, voice, video, or data, each of which have differing characteristics for transmission. It is dynamic to adjust bandwidth requirements as needed rather than wasting network capacity on permanent connections between two stations that communicate infrequently [Ref. 28].

ATM enables enterprise networking by providing a single universal network. It is capable of performing the functions of both LANs and WANs, delivering any kind of

information to any destination. ATM can also be integrated with traditional LAN or WAN segments. This might be of particular interest to an organization that desires to upgrade to ATM, but wants to spread the costs out over a period of time, and thus can upgrade incrementally [Ref. 28].

ATM is independent of upper layer protocols. This allows it to reside in current network architectures, and also eases the transition from current network technologies to ATM in the future [Ref. 54]. ATM is also a highly efficient technology. By establishing VCs before data transfer, ATM avoids having to consult routing information in each packet, which results in higher throughput of data [Ref. 28].

### 2. Disadvantages of ATM

The primary disadvantage of ATM is the high cost involved in its implementation. Network switches cost between $5,000 - $12,000. Simply installing the fiber optic cable, over which ATM was designed to operate, is a large initial cost for an organization to absorb. As the technology matures, it is expected that prices will drop, but ATM will still remain relatively expensive compared to other desktop oriented high-speed solutions [Ref. 55].

Another major disadvantage of ATM is that many of the standards are young or still under development. There are various ATM products for sale today that are incompatible with each other, which makes many organizations hesitant to make the move to ATM until the standards have had time to mature [Ref. 55].

## G. MIGRATING TO ATM

ATM allows for a variety of methods for migrating from your existing system to an ATM system. One method is to rely on ATM for backbone connectivity. This can be accomplished through the use of a single ATM switch connecting multiple Ethernet LAN

segments. Segments of the LAN can be upgraded incrementally, based on which users have the greatest needs for ATM services to the desktop [Ref. 28].

Another option for organizations with widely distributed users would be to implement ATM on a wider scale right away. This might mean using an ATM service provider, such as many telecommunications carriers, to provide commercial service. The organization can purchase just the amount of ATM capability it requires without incurring large infrastructure costs [Ref. 28].

Current ATM products vary greatly in the capabilities they provide. To ease the transition to ATM and get the most out of the products you purchase, you need a solution that offers the following [Ref. 28]:

1. Basic ATM connectivity
2. Ability to handle high traffic volumes with fast response times
3. Reliability
4. Support for a variety of physical media
5. Smooth integration with existing network infrastructure
6. Support for a variety of access and trunk speeds
7. Integral routing and management capability
8. Support for SNMP
9. Support for incremental growth.

## H. CONCLUSIONS

With the various trends in telecommunications today, organizations need networking technologies that support a variety of needs and are flexible to the changes in those needs. Higher end applications and interactive multimedia are driving some of those requirements, such as, the need for a technology that is *fast*, has a *high bandwidth*, and is *flexible* to changes in network requirements. Organizations want to be able to offer the greatest amount of services to the widest dissemination of its members under a

variety of differing circumstances. ATM is at the forefront of being able to provide organizations with this kind of flexibility. With its technical capabilities, wide range of applications, and level of support throughout industry, ATM will provide the networking services of the future.

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